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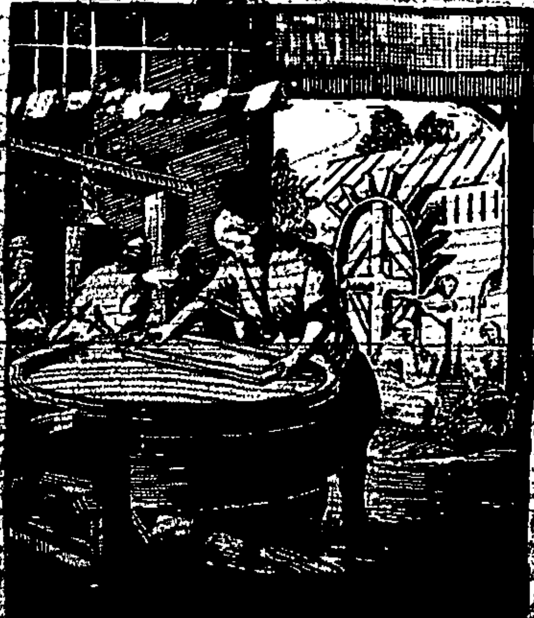

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THE APPLICATION OF CORRUGATED BOXES MADE WITH SULFURIZED BOARD TO THE PACKAGING AND STORAGE OF MEAT

Project 1108-3

Progress Report Seven

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

November 1, 1952

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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APPLETON, WISCONSIN

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INTRODUCTION

The development of a successful method of impregnating corrugating medium with sulfur has made possible the development of the Citrus Box with its unique property of good performance at high humidity. The lack of adequate performance at high humidity, without upgrading the components, has been one of the most serious obstacles to the expanding use of corrugated boxes, particularly in the produce field where, for reasons of preservation, low temperatures and high humidities are desirable. The current expansion in the board field makes it necessary, if the industry is to enjoy a favorable position, to expand the use of corrugated boxes and thereby capture markets which heretofore have been denied them by reason of economy or performance.

One such market would appear to be the application of corrugated boxes in the meat industry. The United States consumes more meat per capita than probably any other nation and the yearly consumption of boxes by this industry is of such magnitude as to make it an appealing "plum" if a corrugated box could be made which would be satisfactory both economically and performance-wise. The current practice in the meat industry is to use either wood or fiberboard boxes for the packaging of meats such as loins, hams, bacon, casings, pork trimmings, ham butts, etc. The majority of the meats are stored at temperatures slightly above freezing although there are a few commodities which are quick frozen and stored at subzero temperatures. Analysis of the requirements of a meat box revealed that they were for the most part similar to those governing the shipment of citrus fruit and which had been successfully met by the Citrus Box construction. It seemed worthy therefore, in view of the potential tonnage involved, to investigate the possible application of corrugated boxes made with sulfurized board in the packaging and storage of meat. Consequently, a study was initiated for this purpose.

In setting up the study, The Institute of Paper Chemistry was fortunate in obtaining the co-operation of a well-known meat packer who was interested in the comparative performance of wood, solid fiber and the "sulfurized" corrugated box. Samples of solid fiber boxes from commercial lots were obtained from Oscar Mayer gratis which served as a baseline or reference. As originally planned, the study was to include wooden meat boxes as well as the fiberboard. However, the former was never obtained; therefore, the present study is a comparison of the relative performance of solid fiber and "sulfurized" corrugated meat boxes.

MATERIALS USED

The materials used in this study consisted of two lots of solid fiber boxes obtained from Oscar Mayer and Co., Madison, Wisconsin. In addition, four lots of commercially run sulfurized boxes were obtained. Two lots were made by the Menasha Wooden Ware Corporation and the other two by the Container Division of International Paper Company, Georgetown, South Carolina.

The solid fiber boxes were taken from commercial lots of boxes. Each lot was a different size and represented a different manufacturer. One of the lots was an all-purpose R.S.C. box for use at normal refrigeration conditions and the other was a Bliss "Freezur" box for use at subzero temperatures. The specifications for these two types of boxes are given below:

BOX SPECIFICATIONS

All Purpose Box

Box Style:	R.S.C.	
Material:	275-lb. solid fiber	
Liner:	Jute	
Caliper:	0.090 in.	
Size:	17 x 12-1/2 x 9-1/2 in.	
Blank Size, sq. ft.:	9.793	
Volume, cu.ft.:	1.170	
Printing Instructions:	2 - 17 x 9-1/2 panels	F-4
	1 - 12-1/2 x 9-1/2 panel	F-10A
	1 - Top Flap	F-2
Manufacturer's Joint:	Single-stitched	
Products:	70-lb. boiled hams	
	45-lb. hog casings	

Freezur Box

Box Style:	Bliss No. 2-4
Materials:	350-lb. solid fiber (body)
	0.120-400-lb. solid fiber (ends)
Liner:	Kraft

Freezur Box (continued)

Size:	23-1/2 x 10 x 9-1/2 in.
Volume, cu. ft.:	1.294
Blank Size, sq. ft.	11.053
Caliper:	0.100 (body)
Special Features:	2-in. center overlap, 4-in. inner flaps, paraffined inside; waterproof chip throughout
Products:	52-lb. Boston butts 80-lb. pork trimmings 75-lb. miscellaneous

The four lots of corrugated boxes consisted of the following:

1. One sample lot of A-flute, 275-lb. R.S.C., size 17 x 12-1/2 x 9-1/2 stitched, fabricated with kraft liners and sulfur-impregnated semichemical medium using starch on the adhesive.
2. One sample lot of B-flute, 275-lb. R.S.C., size 17 x 12-1/2 x 9-1/2 stitched, fabricated with double-face kraft liner, single-face jute liner and sulfur-impregnated semichemical medium using starch as the adhesive.
3. One sample lot of 2-4 Bliss size 23-1/2 x 10 x 9-1/2 fabricated with jute liners and sulfur-impregnated semichemical medium using starch as the adhesive. Both body and ends were 350-lb. B-flute. Paraffined inside. Flutes vertical on both ends and body.
4. One sample lot of 2-4 Bliss size 23-1/2 x 10 x 9-1/2 fabricated with 90-lb. kraft liners and sulfur-impregnated Chemfibre medium using starch as the adhesive. Both body and ends were 350-lb., A-flute, paraffined inside. The flutes were vertical on both ends and body.

The Institute code identifications for these boxes were as follows:

Institute Code Identification:	NOD-111
Box Style:	Bliss
Materials:	B-flute board
Liner:	Jute
Corrugating Medium:	Semichemical (sulfur-impregnated)
Adhesive:	Starch
Size:	23-1/2 x 10 x 9-1/2-in.
Volume:	1.294 cu. ft.
Blank Size:	11.053 sq. ft.
Special Features:	2-in. center overlap 4-in. inner flaps; paraffined inside
Basis Weight, lb./M ft^2:	
Single-face Liner:	121
Double-face Liner:	108

Institute Code Identification:	NOD-113
Box Style:	R.C.S.
Materials:	B-flute board
Liners:	Single-face--Jute Double-face--Kraft
Corrugating Medium:	Semichemical (sulfur-impregnated)
Adhesive:	Starch
Size:	17 x 12-1/2 x 9-1/2 in.
Volume:	1.170 cu. ft.
Blank Size:	9.793 sq. ft.

Institute Code Identification:	NOD-113 (continued)
Manufacturer's Joint:	Single stitched
Basis Weight, lb./M ft.^{2}:	
Single-face Liner:	86
Double-face Liner:	72

Institute Code Identification:	NOD-114
Box Style:	R.S.C.
Materials:	275-lb. solid fiber
Caliper:	0.090 in.
Liner:	Jute
Size:	17 x 12-1/2 x 9-1/2 in.
Volume:	1.170 cu. ft.
Blank Size:	9.793 sq. ft.
Manufacturer's Joint:	Single-stitched

Institute Code Identification:	NOD-112
Box Style:	Bliss No. 2-4
Material:	350-lb. solid fiber (body) 400-lb. solid fiber (ends)
Caliper:	0.100 in. (body) 0.120 in. (ends)
Liner:	Kraft
Size:	23-1/2 x 10 x 9-1/2 in.
Volume:	1.294 cu. ft.
Blank size:	11.053 sq. ft.
Special Features:	2-in. center overlap; 4-in. inner flaps; paraffined inside; waterproof chip throughout

Institute Code Identification: NOD-117

Box Style:	R.S.C.
Material:	A-flute board
Liner:	Kraft
Corrugating Medium:	Chemfibre (sulfur-impregnated)
Adhesive:	Starch
Size:	17 x 12-1/2 x 9-1/2 in.
Volume:	1.170 cu. ft.
Blank Size:	9.793 sq. ft.
Manufacturer's Joint:	Single-stitched
Basis Weight, lb./M ft.^{2}	
Single-face Liner:	68
Double-face Liner:	71

Institute Code Identification: NOD-116

Box Style:	Bliss
Materials:	A-flute board
Liner:	Kraft
Adhesive:	Starch
Corrugating Medium:	Chemfibre (sulfur-impregnated Double-face Side)
Size:	23-1/2 x 10 x 9-1/2
Volume:	1.294 cu. ft.
Blank Size:	11.053 sq. ft.
Special Features:	Paraffined inside

Institute Code Identification: NOD-116 (continued)

Basis Weight, lb./M ft.^{2}

Double-face Liner:	92 (ends)	92 (body)
Single-face Liner:	89 (ends)	93 (body)

GENERAL PROCEDURE

Preconditioning of Boxes Subjected to 85% Relative Humidity

The boxes subjected to 85% relative humidity were first preconditioned for at least 24 hours in an atmosphere maintained at 73°F. and less than 35% R.H. and for at least 48 hours in an atmosphere maintained at 73°F. and 50% R.H.

Closure of Boxes Subjected to 85% Relative Humidity

The boxes selected for compression and fatigue testing were closed in the 50% R.H. and 73°F. atmosphere and were subsequently removed to the high humidity atmosphere. The Bliss style boxes were closed by stitching and the R.S.C. boxes by sealing with Dupont 77 adhesive.

The bottoms of the R.S.C. boxes and ends of the Bliss boxes selected for drop testing were closed as indicated above and the boxes were then loaded as described below under "12-inch Corner Drop" before final closure.

Preconditioning of Boxes Subjected to 50% Relative Humidity

The boxes subjected to 50% relative humidity were first preconditioned for at least 24 hours in an atmosphere maintained at 73°F. and less than 35% R.H.

Closure of Boxes Subjected to 50% Relative Humidity

The boxes subjected to 50% relative humidity were closed after 24 hours' exposure to the 50% R.H. and 73°F. atmosphere. The Bliss style boxes were closed by stitching and the R.S.C. boxes by sealing with silicate of soda adhesive. After the necessary closures were made, the boxes for drop testing were filled with bacon which amounted to 48 pounds. The top closure was then completed.

Conditioning Procedure

The conditioning atmospheres, length of conditioning time, and the tests performed on the boxes thus conditioned are shown in Table I.

TABLE I

TESTS MADE FOR EACH TYPE OF PRE-TEST CONDITIONING

	Pre-Test Conditioning				
	73°F.			35°F.	
	50% R.H.	85% R.H.		85% R.H.	
	48 hours	72 hours	30 days	72 hours	30 days
Box Tests					
Top-load compression	x	x	x		x*
End-load compression	x	x	x		x*
12-inch corner drop	x			x	
Box fatigue		x*	x*		x*
Combined Board Tests					
Basis weight	x				
Caliper	x				
Bursting strength	x				
Flat crush	x				
Torsion tear	x				

* Tested at 50% R.H. and 73°F.

TESTING PROCEDURES

Box Tests

Box Compression

For each condition, 5 specimens were tested for end-load and 5 for top-load box compression. Load-deflection curves were obtained for each specimen. The values reported are the averages of the maximum loads sustained by the test specimens in the deflection ranges 0 to 0.75 inch and 0 to 1.00 inch for top-load compression and 0 to 0.50 inch and 0 to 1.00 inch for end-load compression. The deflection at an initial load of 50 pounds was taken as zero deflection.

12-inch Corner Drop

The 12-inch corner drop test was performed by using a sling-type drop tester equipped with a quick-release device. Five loaded specimens were tested for each sample. The Bliss style boxes and the R.S.C. boxes were loaded with 48 pounds of bacon. The loaded boxes were dropped cornerwise one foot until failure occurred. The average of the number of drops to box failure was reported to the nearest 0.1 drop.

Box Fatigue

Box fatigue was carried out using a fatigue tester designed and constructed at The Institute of Paper Chemistry. In brief, this test consists in applying a load to the test specimen and then relieving the load four times a second. The total number of repeat loadings before the test specimen deforms a given amount is taken as a measure of box fatigue.

For each of the conditions indicated in Table I, three specimens were tested on the box fatigue tester which is shown in Figure 1. An effective load of 235 pounds was applied four times per second in the fatigue testing of the R.S.C. boxes. For the testing of the Bliss style boxes, an effective load of 750 pounds was applied four times per second. The boxes were considered to have failed when they had deflected 0.75 inch.

Combined Board Tests

Basis Weight

For each sample, at least five 12 x 12-inch or equivalent specimens were weighed to the nearest 0.001 lb. on a Toledo basis weight scale. The average basis weight was reported to the nearest pound.

Caliper

Two thickness measurements were made on each of at least five 12 x 12-inch specimens per sample. The two readings on each specimen were made at diagonally opposite corners. The average of the caliper readings was reported to the nearest point.

Bursting Strength

The bursting strength was determined with a Perkins motor-driven "Jumbo" Mullen tester equipped with a special device for applying a definite clamping pressure. The corrugated board specimens were clamped firmly enough to prevent slipping (approximately 30 p.s.i. clamping pressure) and the solid

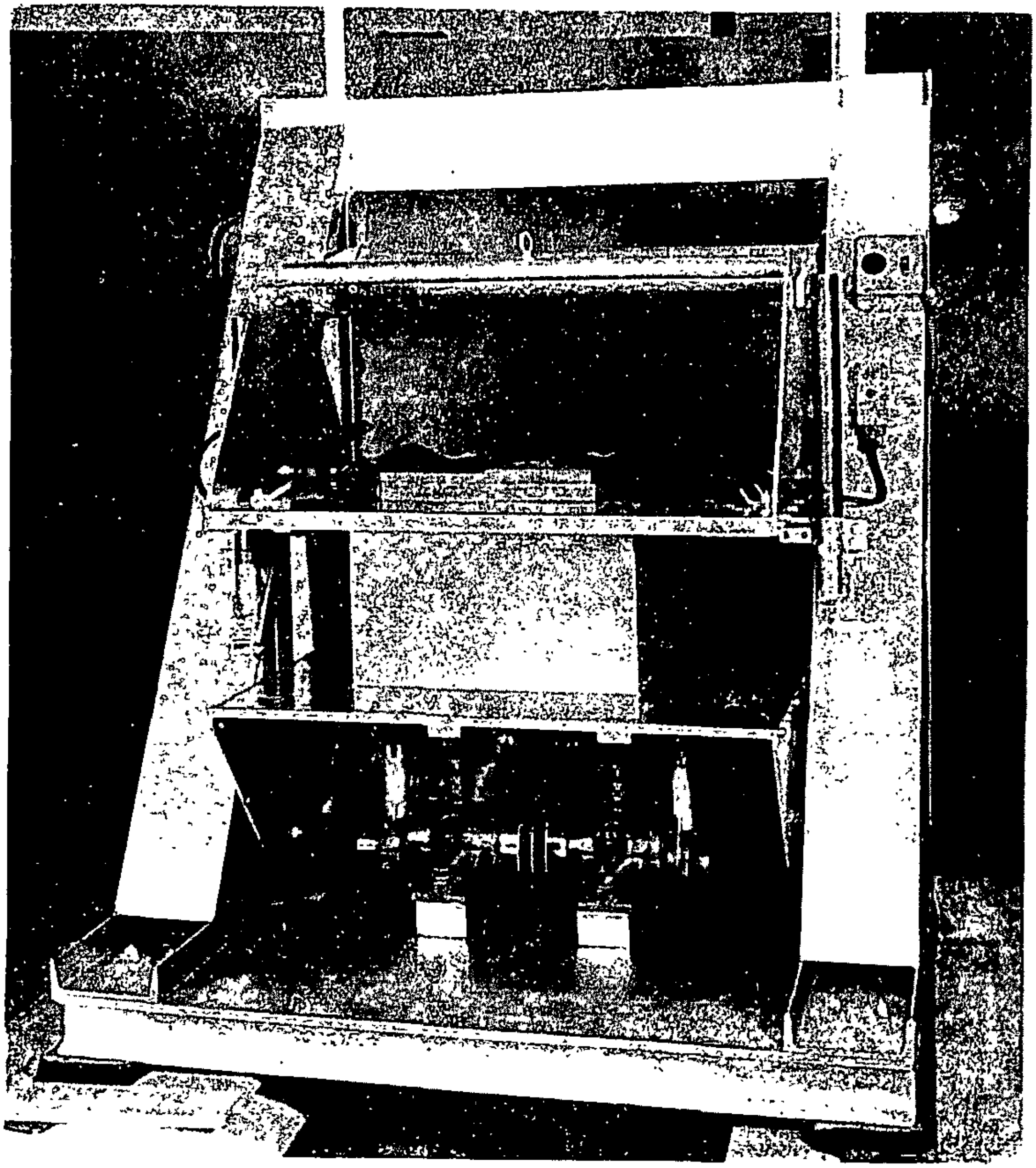


Figure 1

Box Fatigue Tester

fiber specimens were clamped with a pressure of 100 p.s.i. Ten bursting strength determinations were made on each sample, one from each side of five specimens.

Flat Crush

One circular test specimen (5 square inches in area) was cut from each of ten specimens per sample. Each test specimen was tested in a Hinde and Dauch compression tester and was so oriented in the tester that the single-face liner was upward and the machine direction of the facings parallel to the long axis of the beam of the tester. The reported value is the average of the ten determinations calculated to the nearest pound per square inch.

Torsion Tear

Torsion tear determinations were made on ten machine direction specimens, ten cross-machine direction specimens, ten flap scoreline and ten panel scoreline specimens. The specimen size was 5 x 2-1/2 inches and the averages were reported to the nearest inch-ounce. The torsion tear tester is shown in Figure 2 with a specimen in position for testing.

DISCUSSION OF RESULTS

As mentioned previously, the study was designed to investigate the relative merits of three constructions of an all-purpose cold storage R.S.C. box, namely: A-flute, B-flute, and solid fiber. All of the corrugated board was fabricated with sulfur-impregnated corrugating medium.

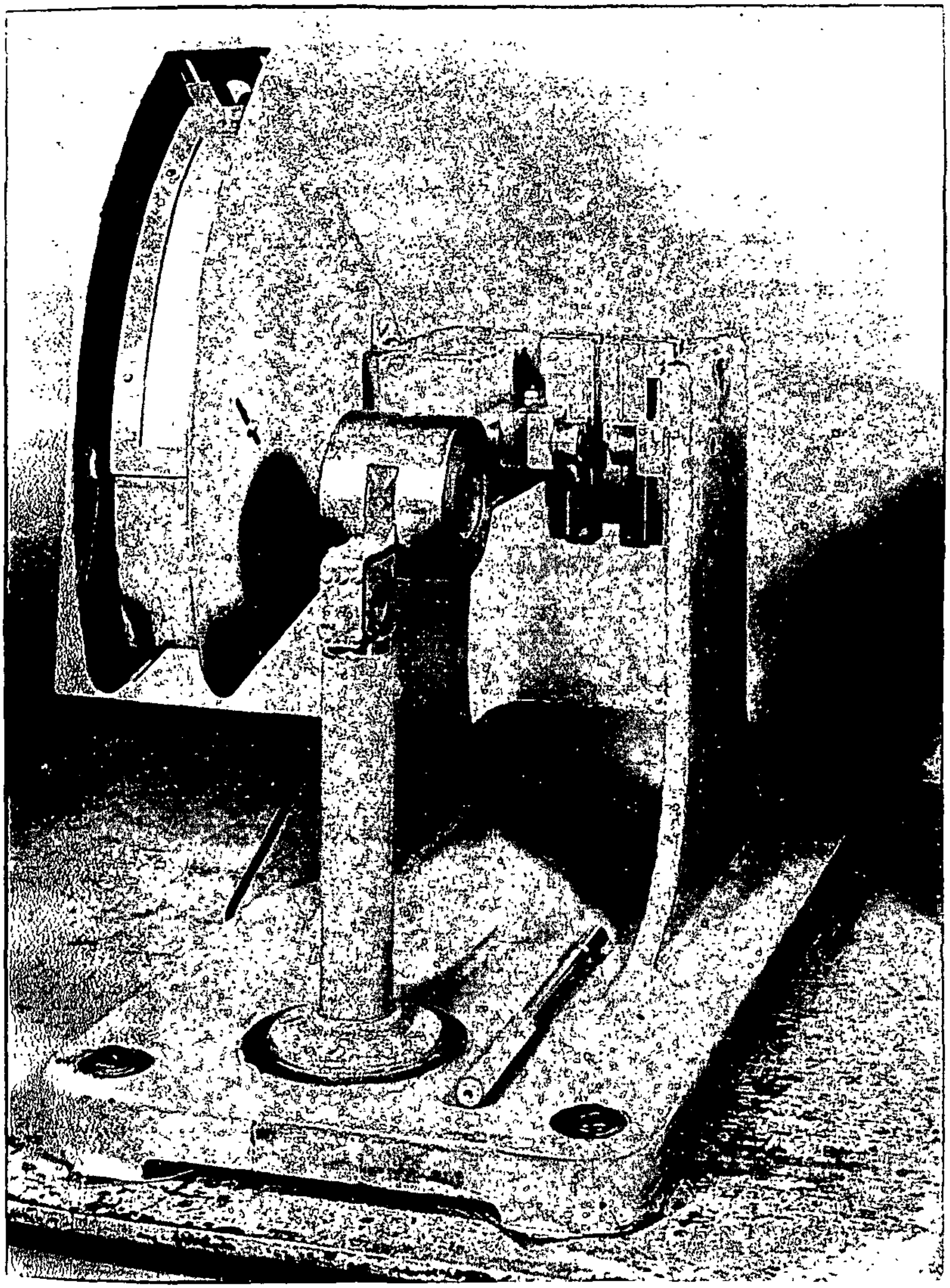


Figure 2

Torsion Tear Tester

The boxes are shown pictorially in Figure 2-a. The pretest conditioning atmospheres to which these boxes were subjected may be seen in Table I. These conditions were chosen to simulate actual use requirements. The box compression test results obtained on the boxes conditioned for 48 hours at 50% R.H. and 73°F. are shown in Table II and grapaically presented in Figure 3. It is evident that the A-flute box is superior both for top- and end-load compression. The solid fiber box exhibited the lowest top- and end-load compression values while the B-flute boxes gave intermediate values. The corrugated constructions were definitely superior.

Drop test results obtained on the boxes conditioned for 48 hours at 50% R.H. and 73°F. are given in Table II and presented graphically in Figure 4. It may be seen in Figure 4 that the solid fiber construction withstood 125 drops whereas the A-flute construction sustained 82.6 drops and the B-flute 69.0 drops. Thus, for rough handling resistance, the solid fiber box appears to be the best.

The box compression results obtained on the boxes conditioned for 72 hours at 85% R.H. and 73°F. are shown in Table III and presented in graphic form in Figure 5. It may be observed that the corrugated boxes exhibited the highest top- and end-load compression values and the solid fiber the lowest. This observation also applies to the results obtained on the boxes conditioned for 30 days at 85% R.H. and 73°F.; these results are given in Table IV and Figure 6.

Box fatigue tests were performed on the boxes conditioned for 72 hours and 30 days at 85% R.H. and 73°F., and the results are given in

TABLE II

BOX TEST RESULTS
(Conditioned at 50% R.H., 73°F. for 48 Hours and Tested at 50% R.H., 73°F.)

Samples		End-Load Compression, lb. Max. Load up to 0.50" Defl.	End-Load Compression, lb. Max. Load up to 1.00" Defl.	End-Load Compression, lb. Defl. at Max. Load	Top-Load Compression, lb. Max. Load up to 0.75" Defl.	Top-Load Compression, lb. Max. Load up to 1.00" Defl.	Top-Load Compression, lb. Defl. at Max. Load	Drop Test, number of drops to failure	Cause of Failure
NOD-113	Max.	1260	1260	0.47	1145	1180	0.79	125	Staples pulled out.
RSC B-flute	Min.	1115	1115	0.37	950	1020	0.59	43	Vertical scoreline tore.
	Av.	1195	1195*	0.44	1045	1080	0.74	69.0	
NOD-114	Max.	780	1150	0.83	845	900	1.00	125	No failure after 125 drops.
RSC, Solid fiber	Min.	580	955	0.71	575	775	0.53	125	Some staples pulled; small
	Av.	720	1065	0.76	720	830**	0.71	125.0	tears along flap scoreline. Delamination between filler and liner evident.
NOD-117	Max.	1300	1300	0.43	1450	1570	0.97	125	Staples pulled out.
RSC A-flute	Min.	1205	1205	0.37*	1350	1380	0.59	47	
	Av.	1250	1250	0.40	1400	1460	0.75	82.6	

* One specimen of this set sustained a greater load at a deflection greater than 1.00 inch than it did up to 1.00-inch deflection.

** Three specimens sustained greater loads at deflections greater than 1.00 inch than they sustained up to 1.00-inch deflection.

TABLE III

BOX TEST RESULTS

(Conditioned at 85% R.H., 73°F. for 72 Hours, Box Compression Tested at 85% R.H., 73°F., Box Fatigue Tested at 50% R.H., 73°F.)

Samples		End-Load Compression, lb. Max. Load up to 0.50" Defl.	End-Load Compression, lb. Max. Load up to 1.00" Defl.	End-Load Compression, lb. Defl. at Max. Load	Top-Load Compression, lb. Max. Load up to 0.75" Defl.	Top-Load Compression, lb. Max. Load up to 1.00" Defl.	Top-Load Compression, lb. Defl. at Max. Load	Box Fatigue, cycles to failure
NOD-113 R.S.C. B-flute	Max.	810	830	0.52	520	520	0.71	266
	Min.	765	765	0.42	460	460	0.47	30
	Av.	785	785	0.47	500	500	0.56	142
NOD-114 R.S.C. Solid fiber	Max.	720	900	0.89	550	565	1.00	62
	Min.	540	630	0.53	440	520	0.82	20
	Av.	630	740	0.74	480	535*	0.93	45
NOD-117 R.S.C. A-flute	Max.	800	800	0.44	905	1035	0.84	1165
	Min.	765	765	0.34	620	935	0.55	1130
	Av.	765	765	0.39	715	980	0.64	1148

* One specimen sustained greater load at deflection greater than 1.00 inch.

TABLE IV

BOX TEST RESULTS

(Conditioned at 85% R.H., 73°F. for 30 Days, Box Compression Tested at 85% R.H., 73°F., Box Fatigue Tested at 50% R.H., 73°F.)

Samples		End-Load Compression, lb. Max. Load up to 0.50" Defl.	End-Load Compression, lb. Max. Load up to 1.00" Defl.	End-Load Compression, lb. Defl. at Max. Load	Top-Load Compression, lb. Max. Load up to 0.75" Defl.	Top-Load Compression, lb. Max. Load up to 1.00" Defl.	Top-Load Compression, lb. Defl. at Max. Load	Box Fatigue, cycles to failure
NOD-113 RSC. B-flute	Max.	730	730	0.58	490	490	0.62	136
	Min.	540	590	0.43	470	470	0.44	123
	Av.	625	645	0.50	480	480	0.54	130
NOD-114 RSC. Solid fiber	Max.	700	720	0.58	465	465	0.56	136
	Min.	510	540	0.54	440	440	0.47	123
	Av.	580	600	0.56	455	455	0.52	130
NOD-117 RSC. A-flute	Max.	710	710	0.48	970	970	0.62	6310*
	Min.	705	705	0.46	910	910	0.60	5002*
	Av.	705	705	0.47	945	945	0.61	5571*

* No failure was obtained.

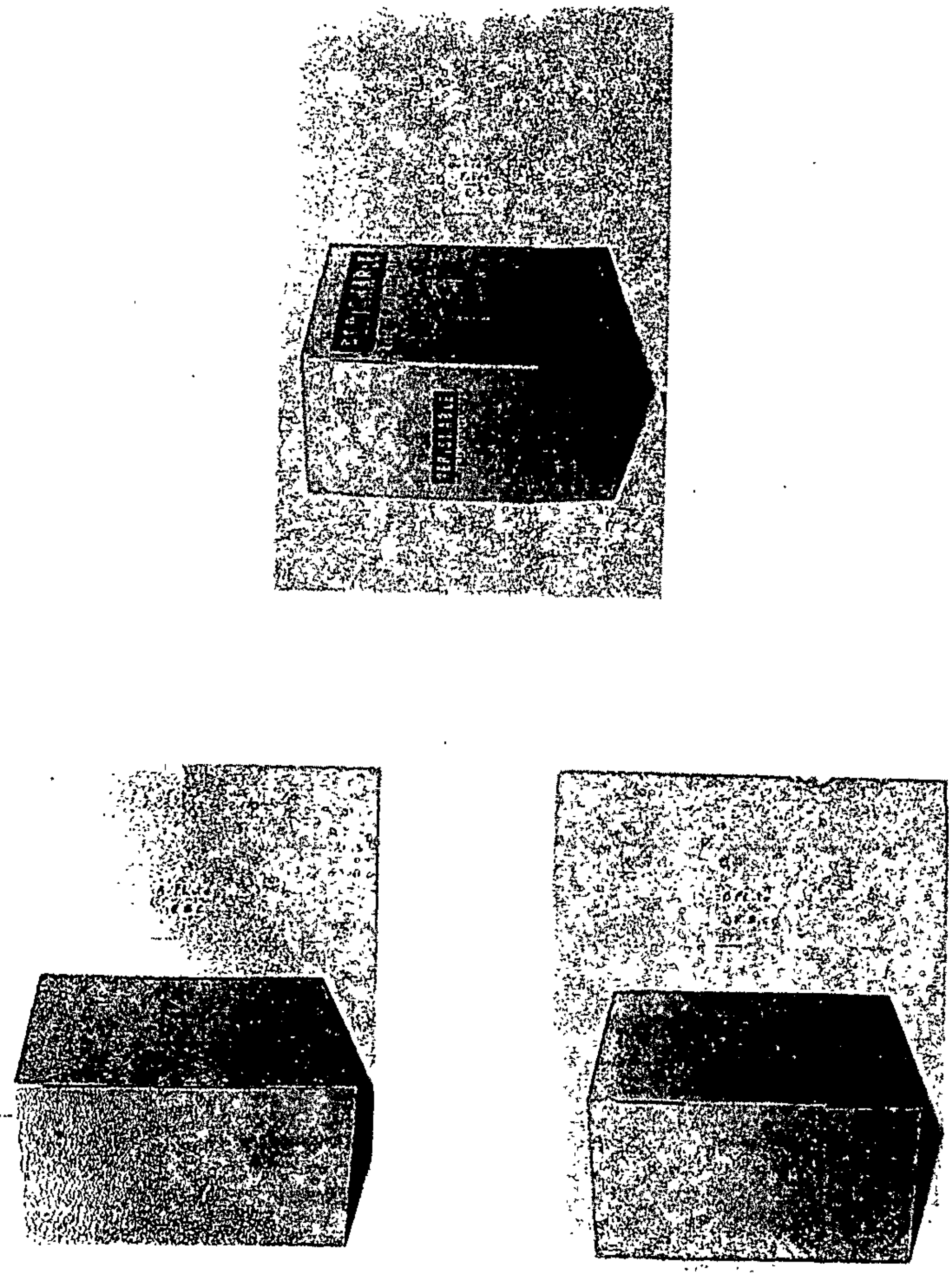


Figure 2A

R.S.C. Boxes

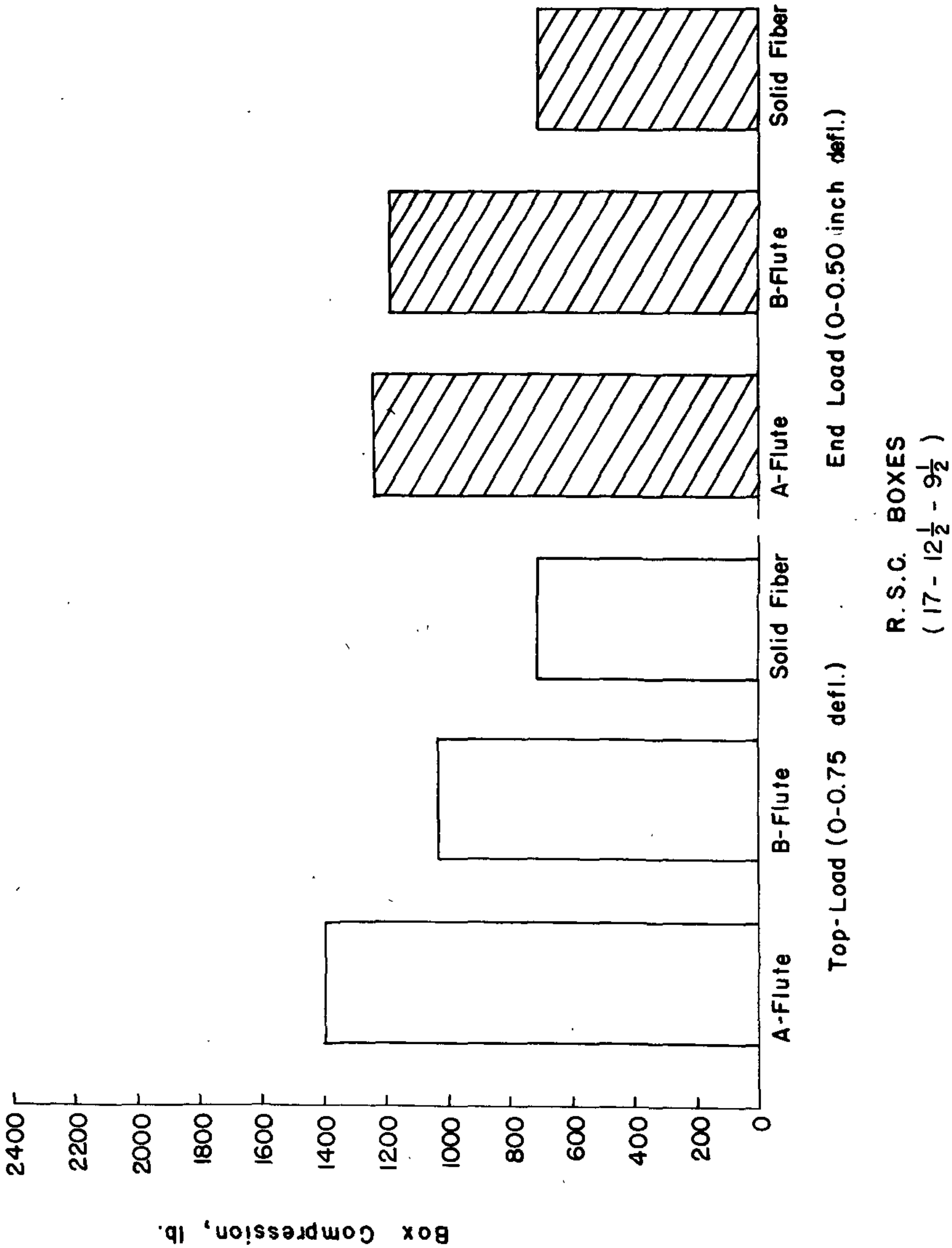


Figure 3

Comparison of Box Compression Results
(Conditioned 48 hours at 50% R.H. and 73°F.)

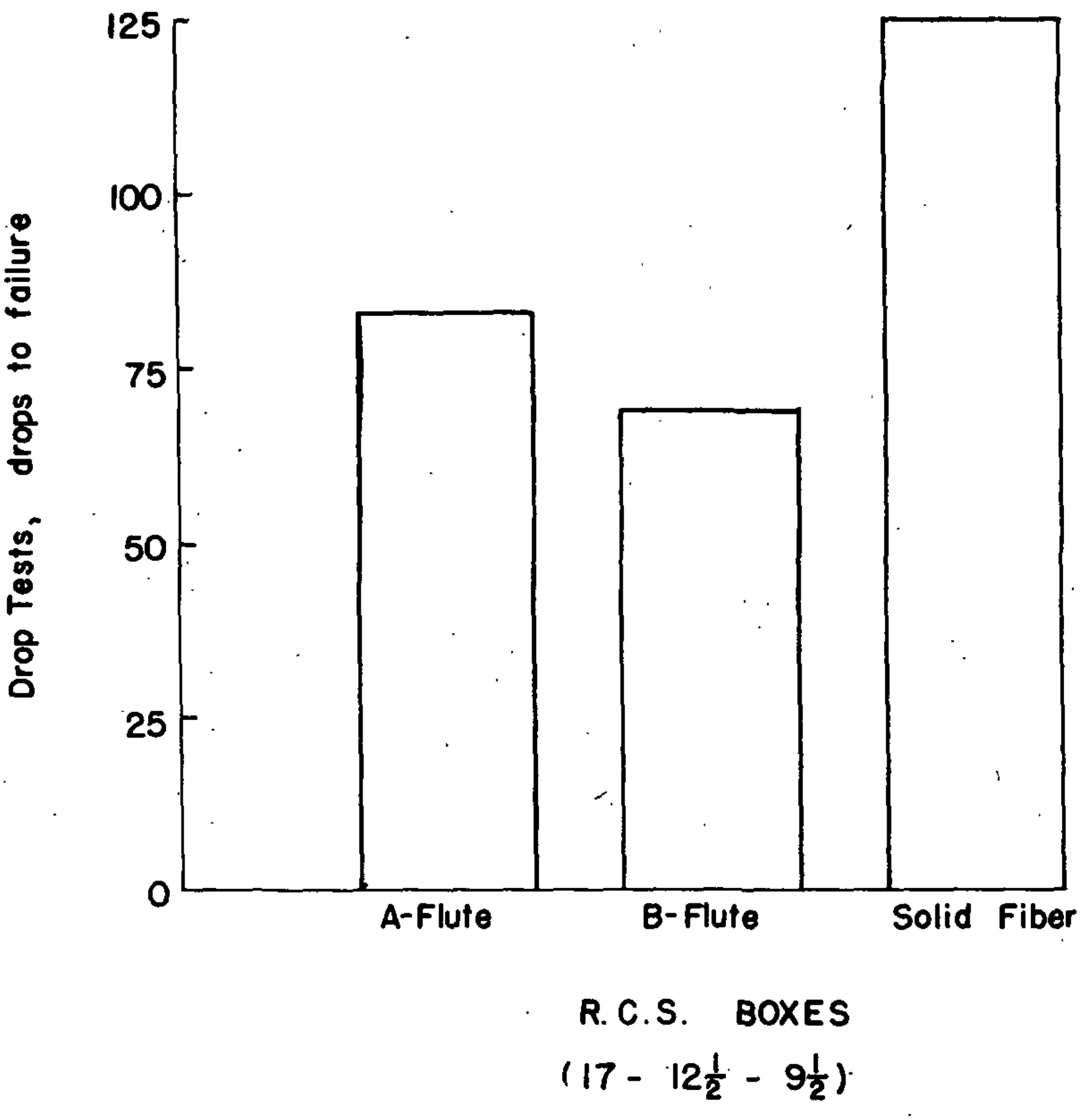
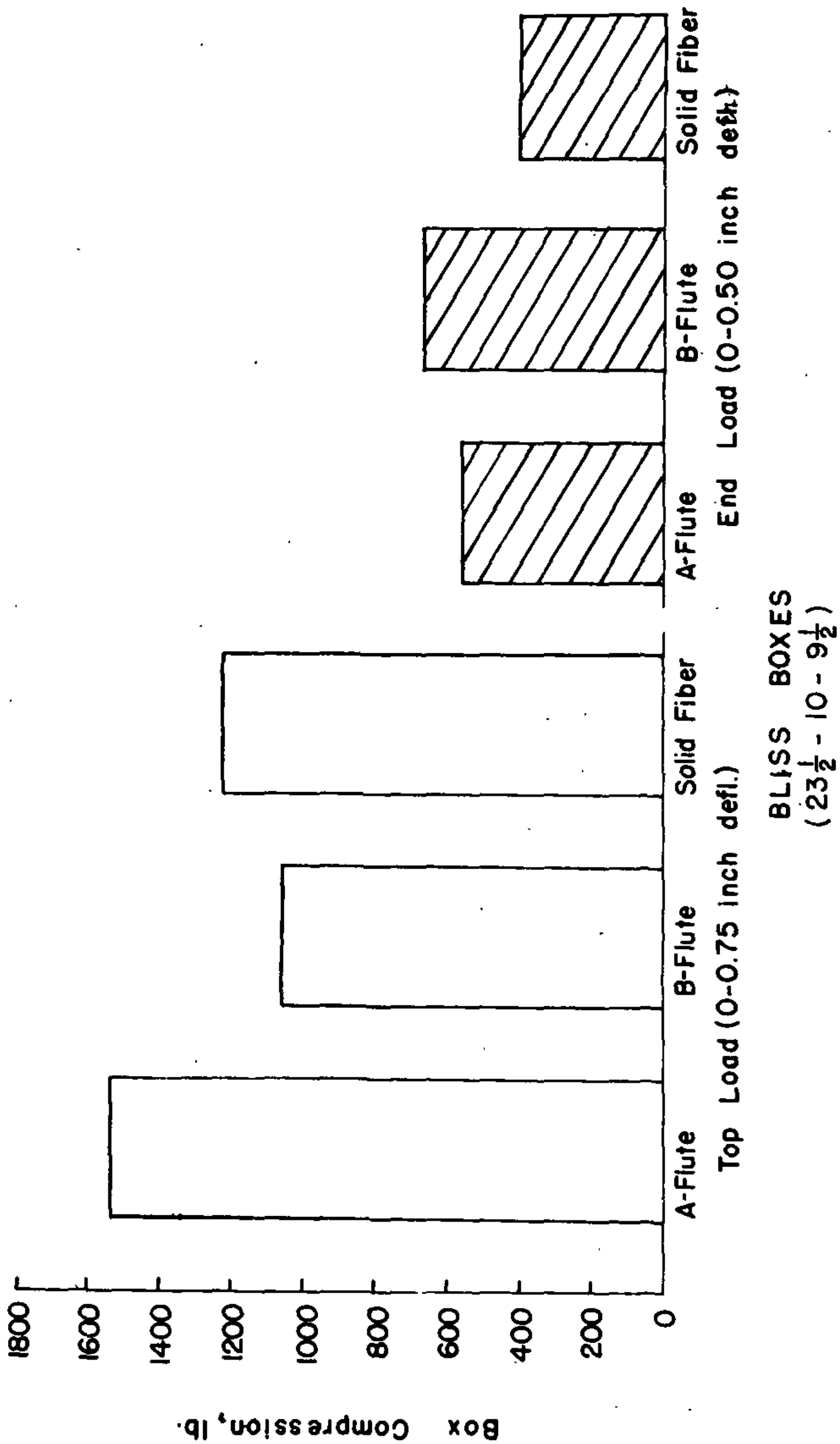


Figure 4

Comparison of Drop Test Results
(Conditioned 48 hours at 50% R.H. and 73°F.)



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Comparison of Box Compression Results
(Conditioned 72 hours at 85% R.H. and 73°F.)

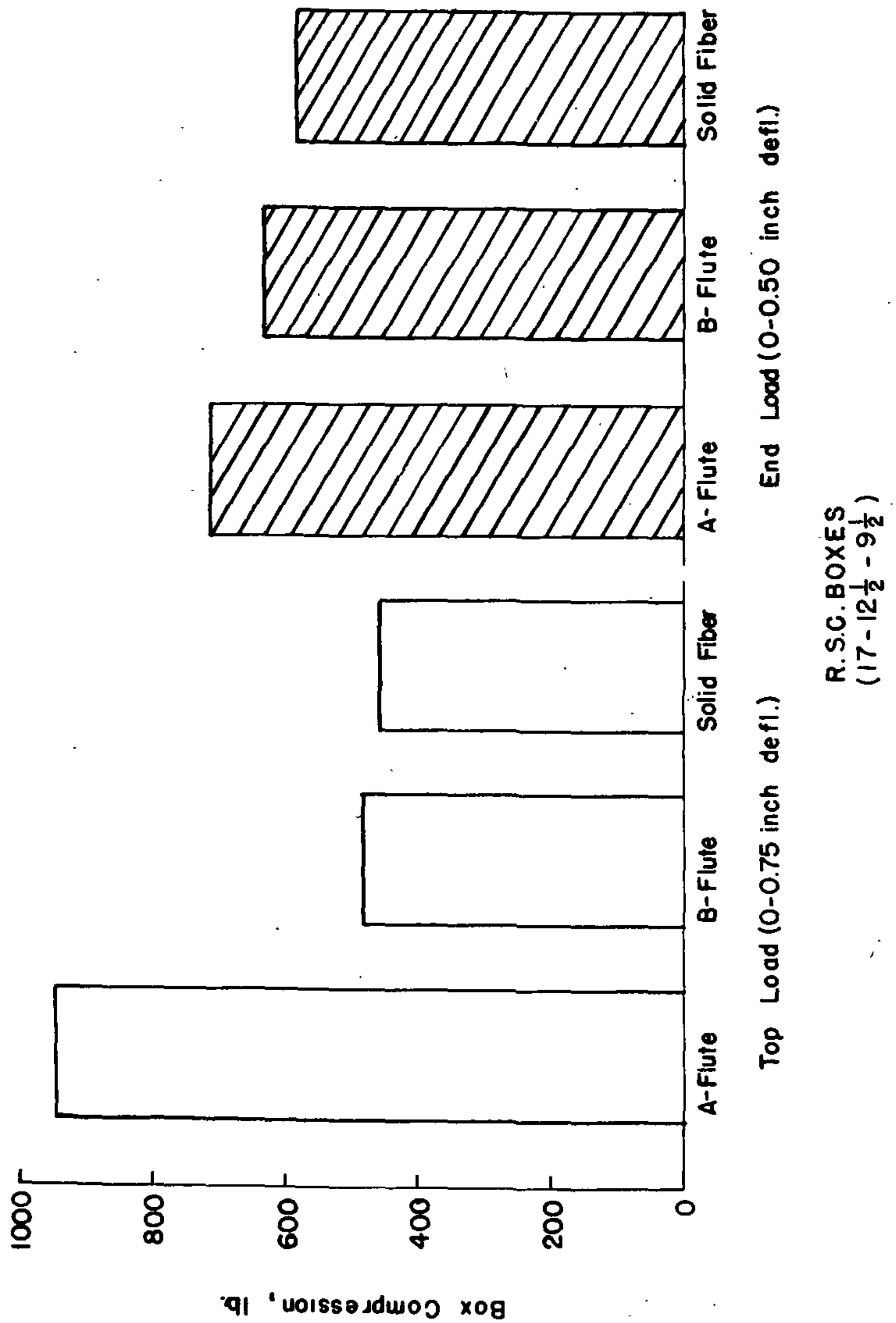


Figure 6

Comparison of Box Compression Results
(Conditioned 30 days at 85% R.H. and 73°F.)

Tables III and IV, respectively. The results are presented graphically in Figures 7 and 8. It may be noted from these results that the fatigue resistance of the A-flute box is far superior to that exhibited by the solid fiber and B-flute boxes.

The drop test results obtained on the boxes conditioned for 72 hours at 85% R.H. and 35°F. are shown in Table V and graphically presented in Figure 9. These results show that the A-flute box has the greatest rough handling resistance followed quite closely by the B-flute box which, in turn, is followed rather closely by the solid fiber box. The rough handling resistance of all three constructions was good.

The A-flute box was tested for top- and end-load box compression after being conditioned for 30 days at 85% R.H. and 35°F. These results are shown in Table VI and are only slightly lower than the corresponding results obtained on the boxes conditioned for 30 days at 85% R.H. and 73°F. Box fatigue tests were also performed on the A-flute box conditioned 30 days at 85% R.H. and 35°F. and it may be noted in Table VI that the fatigue resistance was high.

Thus, of the three constructions of the all-purpose R.S.C. box--A-flute, B-flute, and solid fiber--the A-flute box has the best compression and fatigue resistance strength for the various conditions studied. At standard conditions--50% R.H. and 73°F. for 48 hours--the solid fiber box has the best rough handling resistance followed closely by the A-flute box. However, at conditions involving 85% R.H., the A-flute box is superior.

TABLE V

BOX TEST RESULTS
(Conditioned at 85% R.H., 35°F. for 72 Hours and Drop Tested at 85% R.H., 35°F.)

Sample		Drop Test, drops to failure	Cause of Failure
NOD-113 R.S.C. B-flute	Max.	125	Staples pulled.
	Min.	45	
	Av.	95	
NOD-114 R.S.C. Solid fiber	Max.	125	Staples pulled and flaps tore loose.
	Min.	25	
	Av.	77	
NOD-117 R.S.C. A-flute	Max.	125	Staples pulled. Four of the five boxes tested had not failed after 125 drops.
	Min.	73	
	Av.	115	

TABLE VI

BOX TEST RESULTS

(Conditioned at 85% R.H., 35°F. for 30 days, Box Compression Tested at 50% R.H., 73°F., Box Fatigue Tested at 50% R.H., 73°F.)

Samples		End-Load Compression, lb. Max. Load up to 0.50" Defl.	End-Load Compression, lb. Max. Load up to 1.00" Defl.	End-Load Compression, lb. Defl. at Max. Load	Top-Load Compression, lb. Max. Load up to 0.75" Defl.	Top-Load Compression, lb. Max. Load up to 1.00" Defl.	Top-Load Compression, lb. Defl. at Max. Load	Box Fatigue, cycles to failure
NOD-117 R.S.C. A-flute	Max.	710	710	0.45	860	860	0.65	5000**
	Min.	655	655	0.34	830	830	0.60*	5000**
	Av.	685	685	0.40	840	840	0.62	5000**

* This specimen sustained greater loads at deflections greater than 1.00 inch than it sustained up to 1.00-inch deflection.

** No failure was obtained.

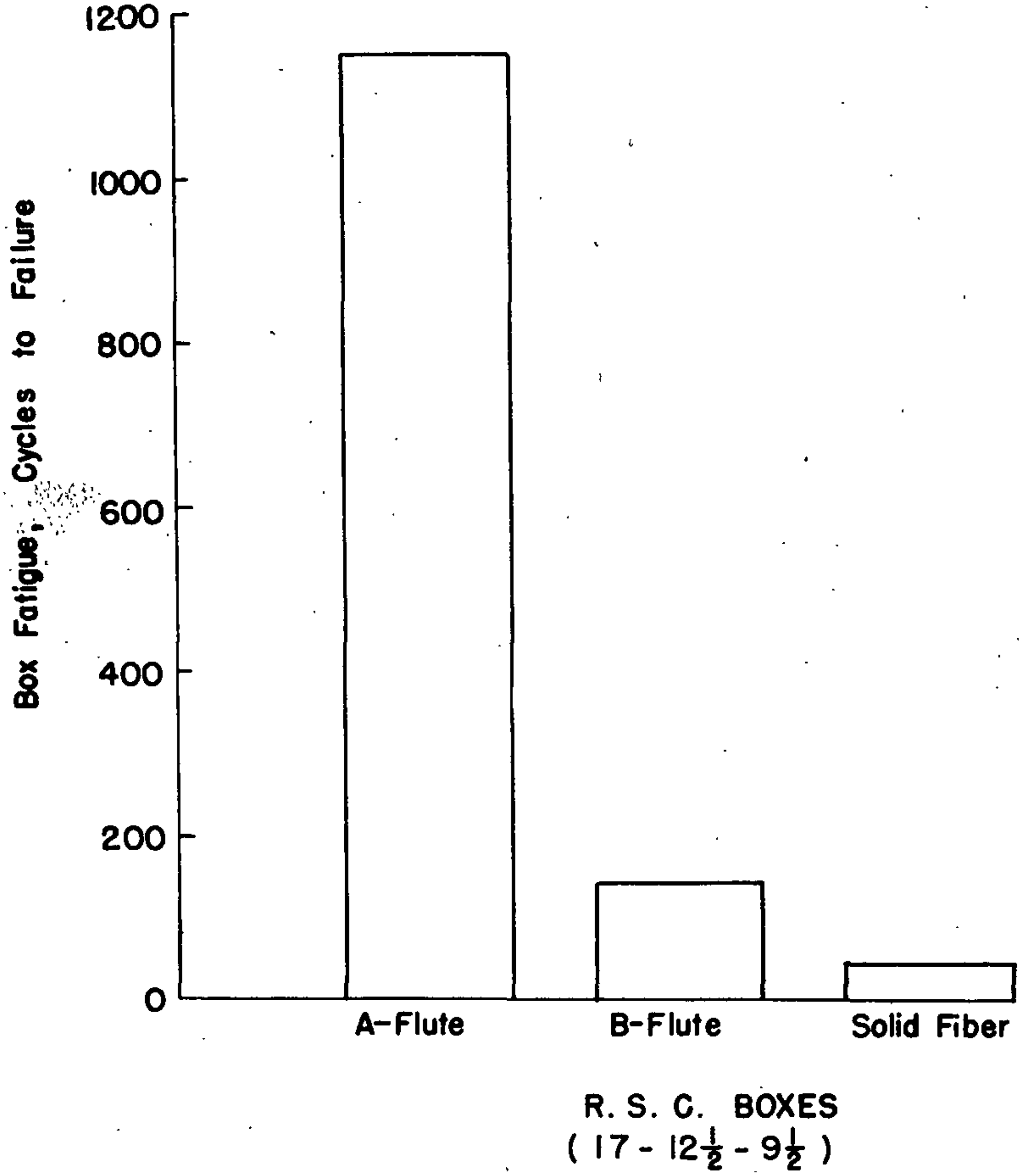


Figure 7

Comparison of Box Fatigue Test Results
(Conditioned 72 hours at 85% R.H. and 73°F.)

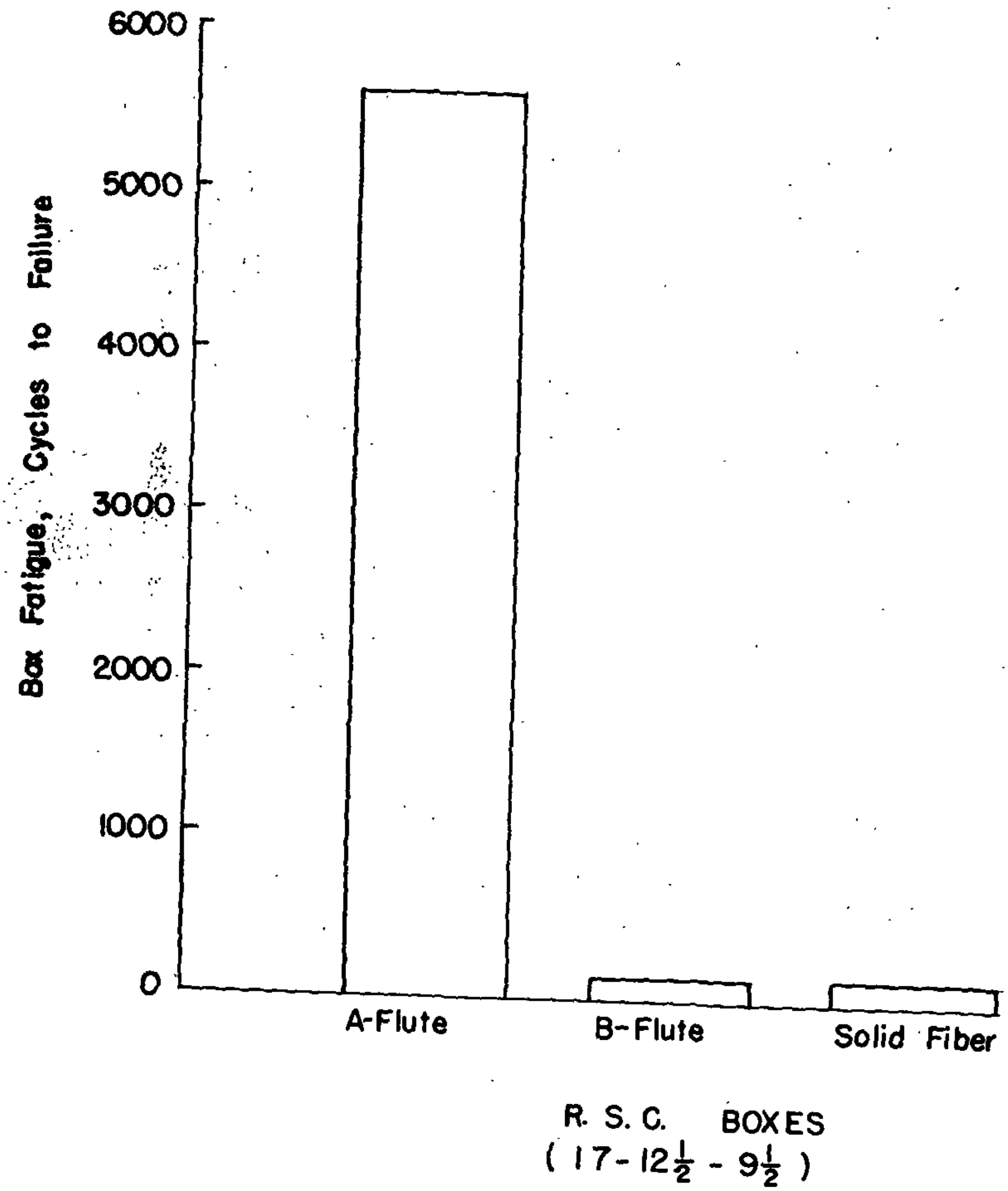


Figure 8

Comparison of Box Fatigue Test Results
(Conditioned 30 days at 85% R.H. and 73°F.)

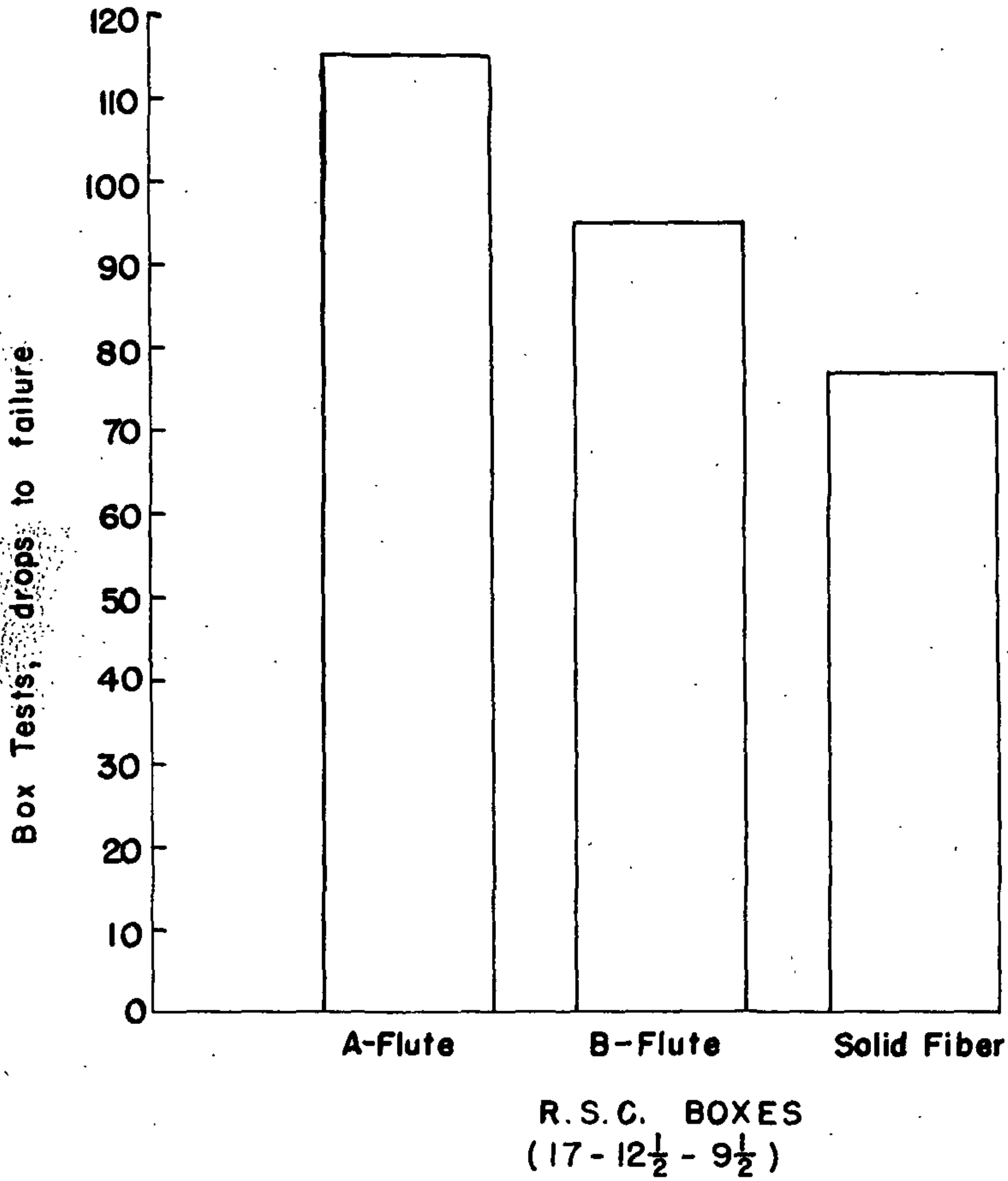


Figure 9

Comparison of Drop Test Results
(Conditioned 72 hours at 85% R.H. and 35°F.)

Therefore, from every viewpoint studied, the R.S.C., A-flute box appears to be the best all-around performer.

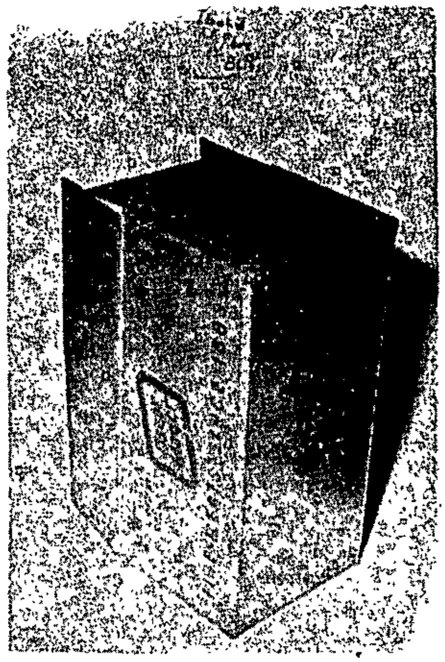
The combined board test results for each construction--A-flute, B-flute, and solid fiber-- re given in Table VII. It may be seen that the solid fiber construction was the heaviest, being about 50% heavier than the corrugated constructions. The bursting strength of the solid fiberboard was considerably higher than that of the corrugated. The flat crush of the B-flute board was somewhat higher than that of the A-flute board as would be expected. The torsion tear results show that the A-flute board exhibited the greatest machine direction tear, the B-flute board the lowest, and the solid fiber, an intermediate value. The highest cross-direction tear values were exhibited by the solid fiberboard, the lowest by the B-flute board and intermediate values by the A-flute board. These high tear values probably are related to the better rough handling resistance associated with the boxes made from A-flute and solid fiberboard.

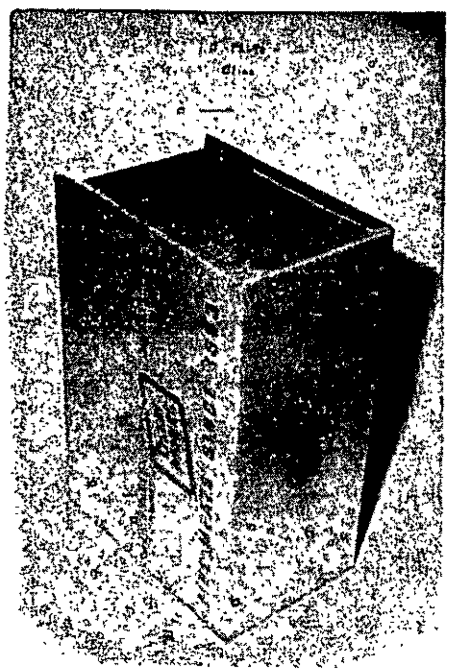
As mentioned earlier, the present study was undertaken to investigate the relative merits of three constructions of an all-purpose R.S.C. cold storage box. This information has been reviewed and discussed in the preceding paragraphs. Also investigated were the relative merits of three constructions--A-flute, B-flute, and solid fiber--of a Bliss style "Freezur" box designed for the storage of commodities, such as meats, for relatively long periods of time at low temperatures and high humidities. These boxes are shown pictorially in Figure 9-a.

TABLE VII

COMBINED BOARD TEST RESULTS
(Conditioned at 50% R.H., 73°F. for 48 Hours and Tested at 50% R.H., 73°F.)

Sample		Basis Weight, lb./M ft.^{2}	Caliper, points	Bursting Strength, p.s.i. g.	Flat Crush, lb./sq. in.	Torsion Tear, in.-oz. In	Torsion Tear, in.-oz. Across	Torsion Tear, in.-oz. Flap Score	Torsion Tear, in.-oz. Panel Score
NOD-113	Max.		144.0	340	64.2	332	336	224	268
R.S.C. B-flute	Min.		135.5	300	47.6	278	308	196	212
	Av.	215	141.0	323	56.3(10-10-10)	315	319	208	232
NOD-114	Max.		99.7	455		410	480	330	414
R.S.C. Solid fiber	Min.		95.5	370		350	392	270	310
	Av.	322	97.2	427		369	446	308	360
NOD-117	Max.		218.5	345	41.5	474	432	370	368
R.S.C. A-flute	Min.		210.0	255	30.7	408	368	296	278
	Av.	206	215.4	282	34.9(10-10-10)	436	398	342	308





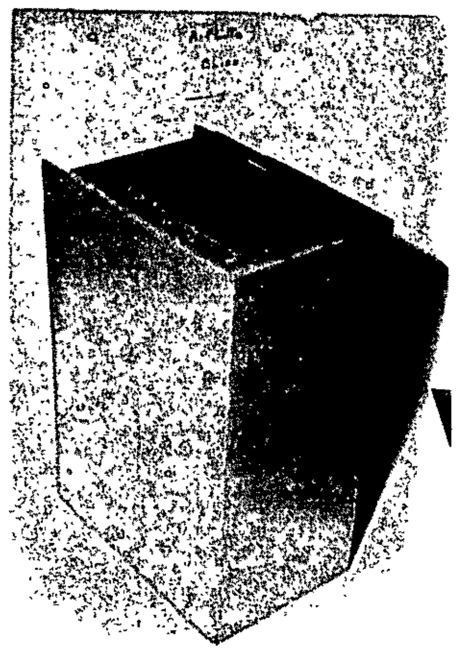


Figure 9-A

Bliss Boxes

The box compression results obtained on the boxes conditioned for 48 hours at 50% R.H. and 73°F. are given in Table VIII and presented graphically in Figure 10. The A-flute box exhibited the highest top-load compression values and the B-flute box the lowest. The A-flute and B-flute boxes gave the highest values for end-load compression whereas the solid fiber box gave substantially lower values than either of the other constructions.

The drop test results for boxes conditioned 48 hours at 50% R.H. and 73°F. are presented in Table VIII and Figure 11. It may be seen that the greatest number of drops was sustained by the B-flute construction and the lowest number by the solid fiber. It may be noted also in Table VIII that double-stitching greatly improved the rough-handling resistance of the A-flute box.

The box compression test results obtained on the boxes conditioned for 72 hours at 85% R.H. and 73°F. are given in Table IX and presented graphically in Figure 12. The highest top-load was sustained by the A-flute box and the lowest by the B-flute. The highest end-load was sustained by the B-flute box and the lowest by the solid fiber. The end-load compression of the A-flute box was relatively close to that of the B-flute box. The box fatigue results are also given in Table IX. It may be noted in Figure 13 that the A-flute construction exhibited box fatigue resistance far in excess of that exhibited by the B-flute or solid fiber construction.

The box compression results obtained on the boxes conditioned for 30 days at 85% R.H. and 73°F. are shown in Table X and graphically presented in Figure 14. It may be noted that the A-flute box had the highest

TABLE VIII

BOX TEST RESULTS

(Conditioned at 50% R.H., 73°F. for 48 Hours and Tested at 50% R.H., 73°F.)

Sample		End-Load Compression, lb. Max. Load up to 0.50" Defl.	End-Load Compression, lb. Max. Load up to 1.00" Defl.	End-Load Compression, lb. Defl. at Max. Load	Top-Load Compression, lb. Max. Load up to 0.75" Defl.	Top-Load Compression, lb. Max. Load up to 1.00" Defl.	Top-Load Compression, lb. Defl. at Max. Load	Drop Test, number of drops to failure	Cause of Failure
NOD-111	Max.	970	1180	0.98	1760	1760	0.74	42	Staples pulled out.
Bliss, B--flute	Min.	870	990	0.45	1625	1625	0.48	15	
	Av.	945	1050	0.81	1720	1720	0.66	24.0	
NOD-112 Bliss, Solid fiber	Max.	590	670	0.73	1900	2060	0.90	10	Vertical scoreline tore.
	Min.	500	530	0.53	1835	1840	0.70	5	
	Av.	540	615	0.63	1860	1915	0.79	7.2	
NOD-116	Max.	995	995	0.85	2565	2565	0.88	17	Staples pulled out.
Bliss, A-flute	Min.	865	940	0.33	2240	2390	0.51	6	Staples pulled out on top.
	Av.	945	975	0.55	2435	2480	0.67	10.8 (77.0*)	Complete failure on top.

* Double-stitched.

TABLE IX

BOX TEST RESULTS

(Conditioned at 85% R.H., 73°F. for 72 Hours, Box Compression Tested at 85% R.H., 73°F., Box Fatigue Tested at 50% R.H., 73°F.)

Sample		End-Load Compression, lb. Max. Load up to 0.50" Defl.	End-Load Compression, lb. Max. Load up to 1.00" Defl.	End-Load Compression, lb. Defl. at Max. Load	Top-Load Compression, lb. Max. Load up to 0.75" Defl.	Top-Load Compression, lb. Max. Load up to 1.00" Defl.	Top-Load Compression, lb. Defl. at Max. Load	Box Fatigue, cycles to failure
NOD-111	Max.	760	760	0.92	1140	1140	0.96	24
Bliss, B-flute	Min.	590	620	0.66	995	995	0.36	15
	Av.	660	710*	0.64	1060	1060	0.60	19
NOD-112	Max.	475	480	0.72	1325	1565	1.00	139
Bliss, Solid fiber	Min.	340	380	0.51	910	1310	0.72	59
	Av.	395	445	0.63	1230	1380	0.82	89
NOD-116	Max.	630	670	1.00	1575	1575	0.61	5000**
Bliss, A-flute	Min.	455	595	0.46	1460	1460	0.49	5000**
	Av.	555	620	0.71	1540	1540	0.53	5000**

* Two specimens exhibited greater loads at a deflection greater than 1.00 inch than they did up to 1.00-inch deflection.

** No failure was obtained.

TABLE X

BOX TEST RESULTS

(Conditioned at 85% R.H., 73°F. for 30 Days, Box Compression Tested at 85% R.H., 73°F., Box Fatigue Tested at 50% R.H., 73°F.)

Samples		End-Load Compression, lb. Max. Load up to 0.50" Defl.	End-Load Compression, lb. Max. Load up to 1.00" Defl.	End-Load Compression, lb. Defl. at Max. Load	Top-Load Compression, lb. Max. Load up to 0.75" Defl.	Top-Load Compression, lb. Max. Load up to 1.00" Defl.	Top-Load Compression, lb. Defl. at Max. Load	Box Fatigue, cycles to failure
NCD-111 Bliss, B-flute	Max.				970	970	0.71	19
	Min.				960	960	0.35	10
	Av.				965	965	0.58	14
NCD-112 Bliss, Solid fiber	Max.				1360	1370	0.85	630
	Min.				1190	1220	0.77	11
	Av.				1260	1280	0.81	218
NCD-116 Bliss, A-flute	Max.				1830	1830	0.61	5000*
	Min.				1730	1730	0.57	34
	Av.				1790	1790	0.59	3345

* No failure was obtained.

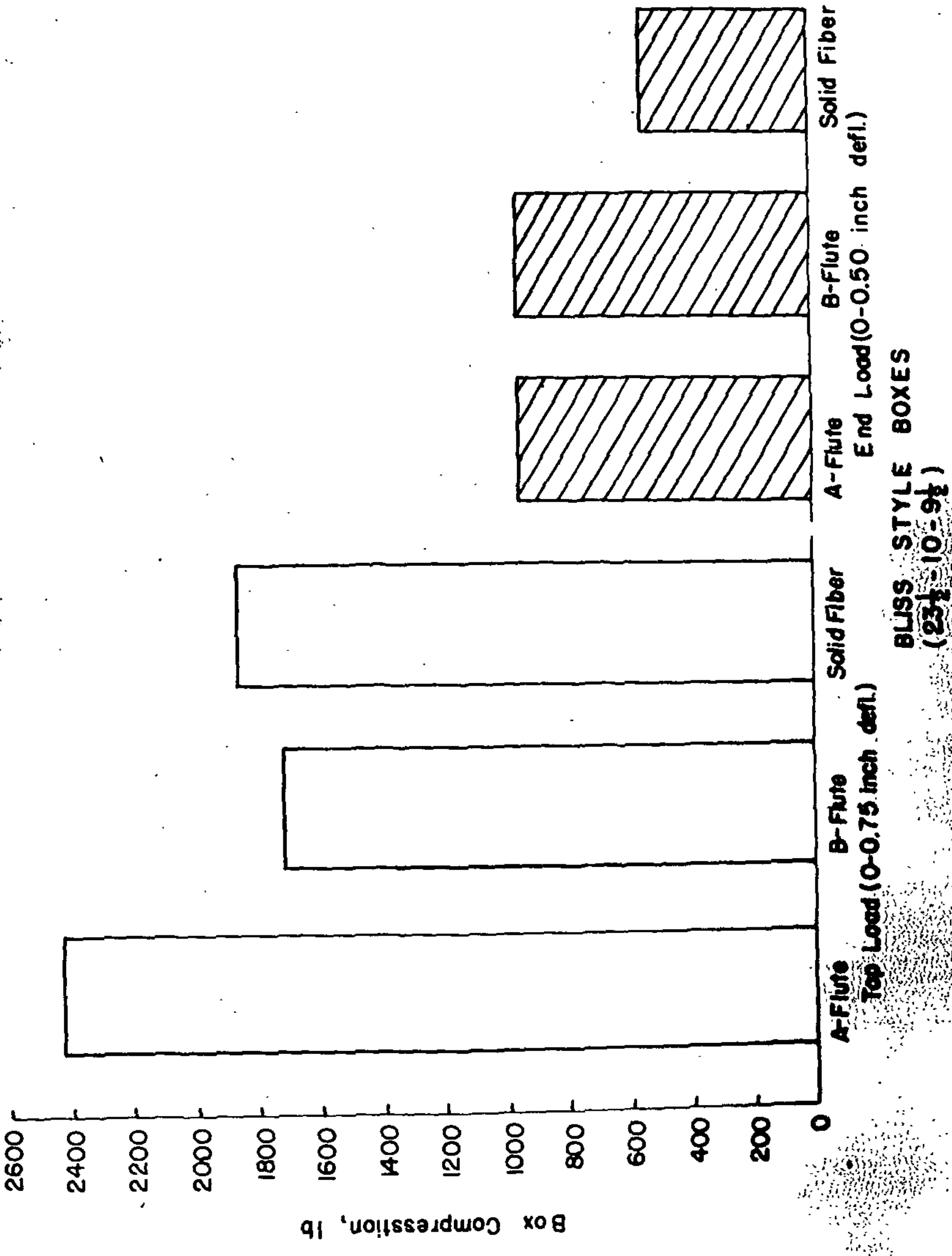


Figure 10

Comparison of Box Compression Results
(Conditioned 48 hours at 50% R.H. and 73°F.)

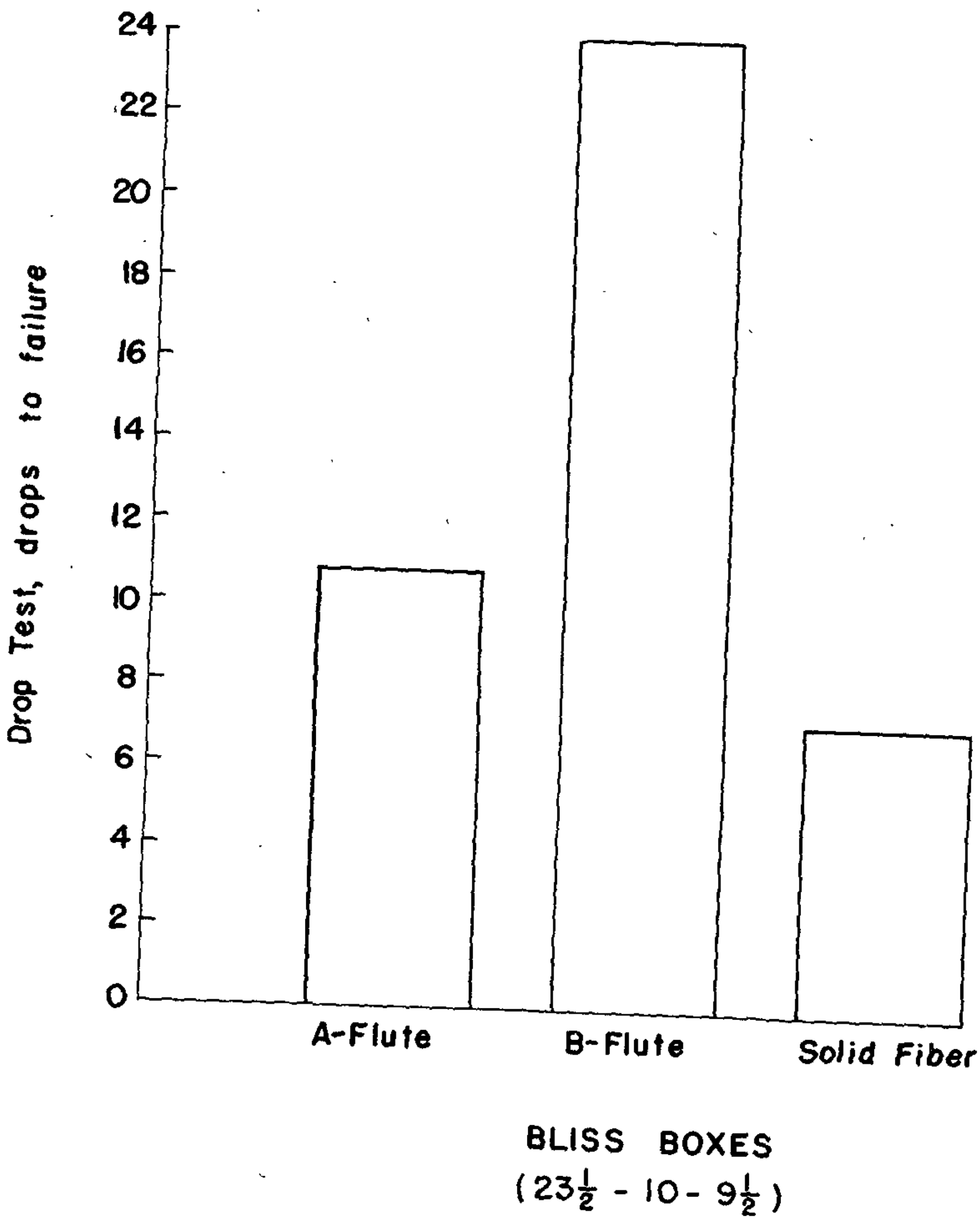


Figure 11

Comparison of Drop Test Results
(Conditioned 48 hours at 50% R.H. and 73°F.)

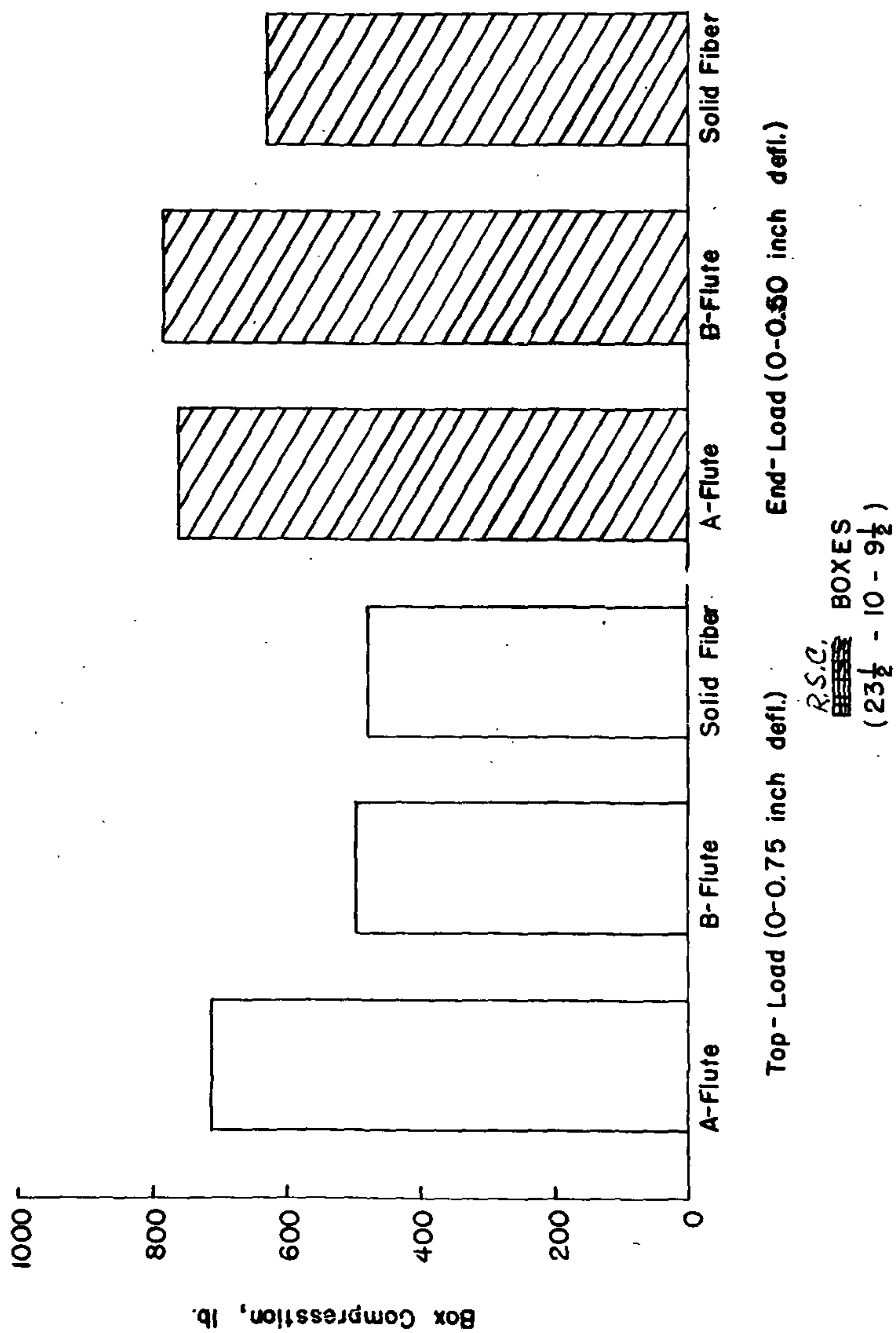


Figure 5 (Figure 12 is on page 22.)

Comparison of Box Compression Results
(Conditioned 72 hours at 85% R.H. and 73°F.)

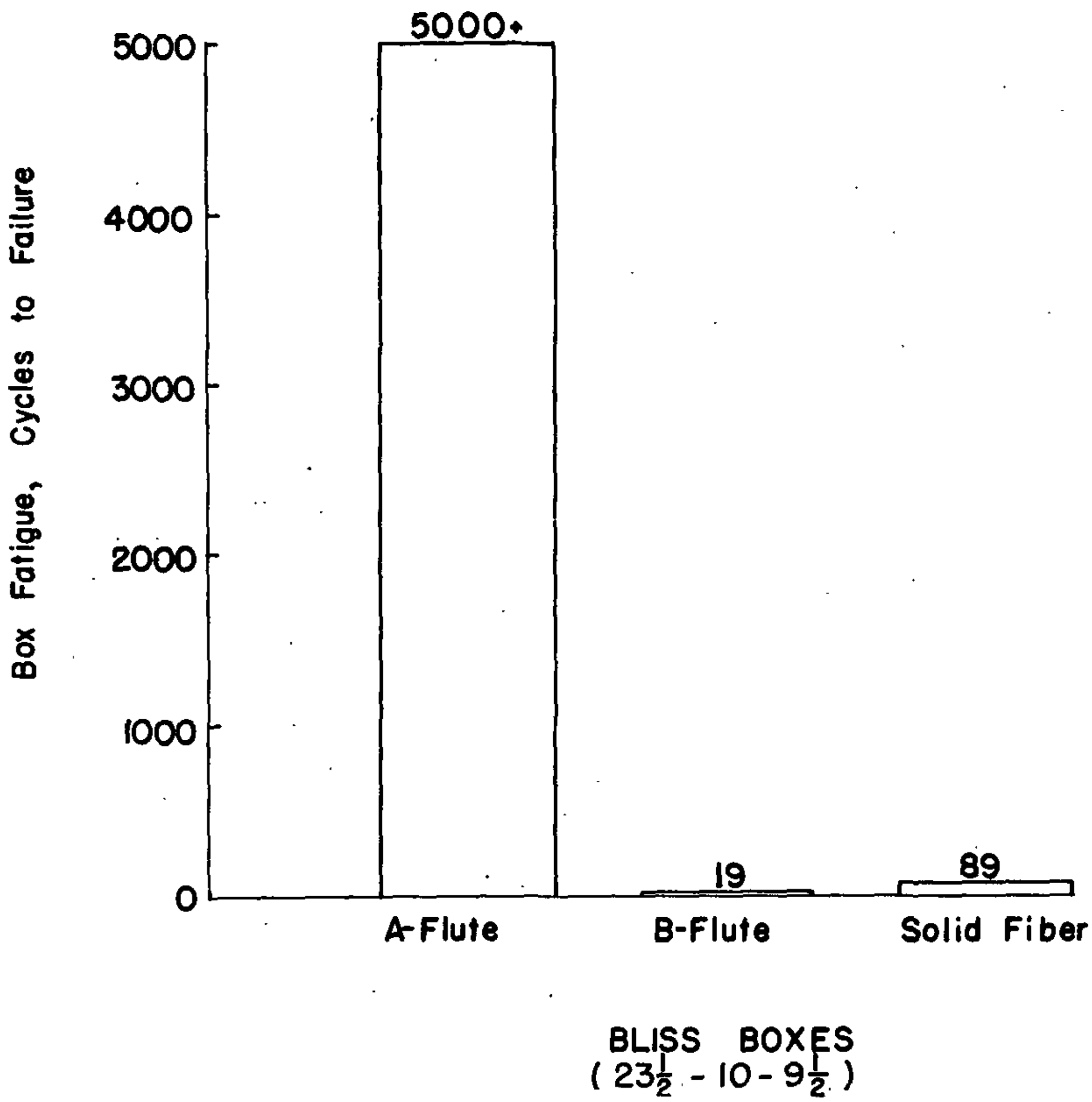


Figure 13

Comparison of Box Fatigue Test Results
(Conditioned 72 hours at 85% R.H. and 73°F.)

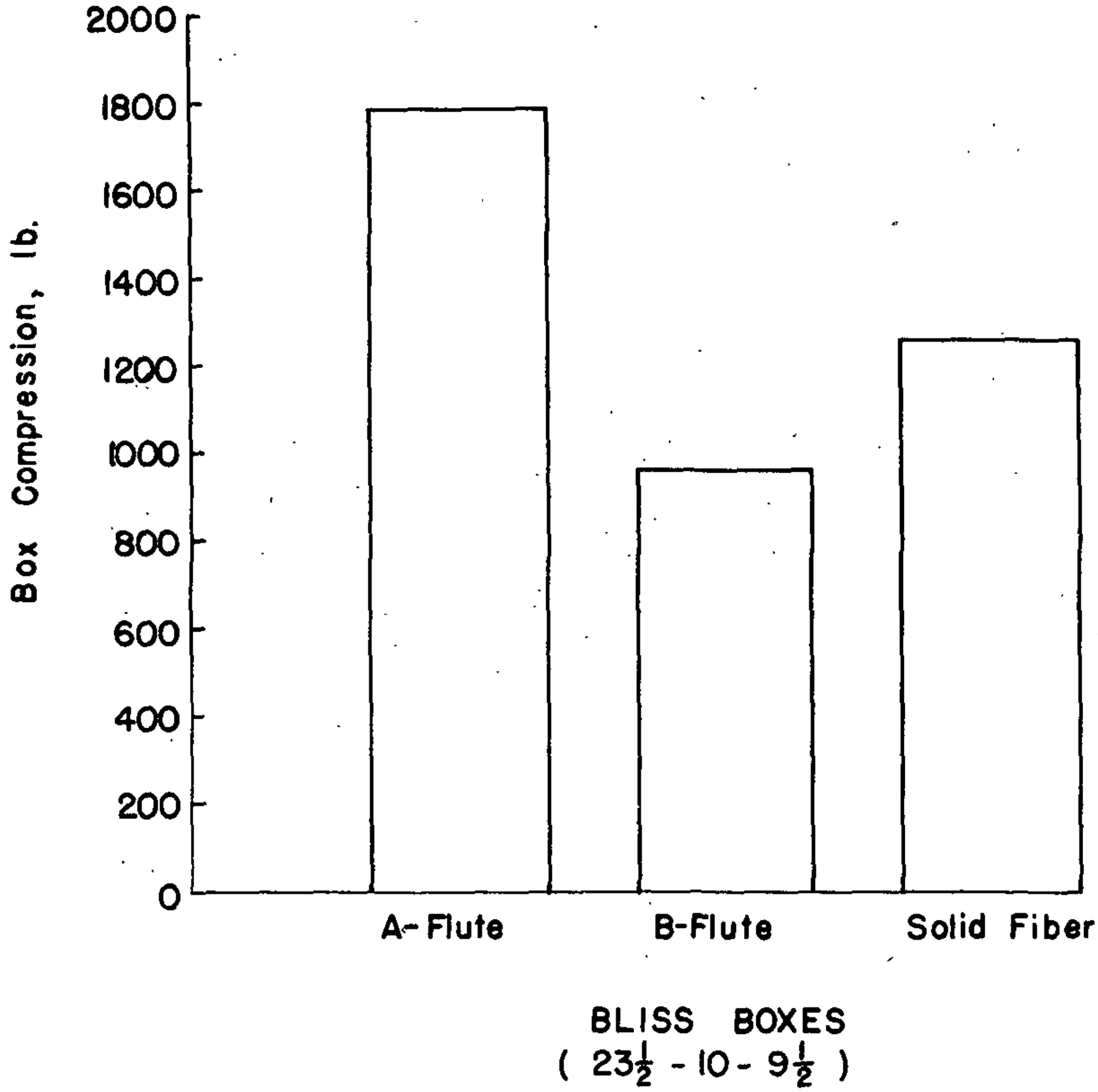


Figure 14

Comparison of Top-Load Box Compression Results
(0-0.75 inch deflection)
(Conditioned 30 days at 85% R.H. and 73°F.)

top-load compression and the B-flute box the lowest. End-load compression tests could not be made because of a limited supply of boxes. Box fatigue tests were run at this condition, and the results are shown in Table X and presented graphically in Figure 15. It may be seen that the A-flute construction exhibited a fatigue resistance much greater than that of the other constructions.

The drop test results obtained on the boxes conditioned for 72 hours at 85% R.H. and 35°F. are given in Table XI and presented graphically in Figure 16. These results show that the B-flute construction sustained the highest number of drops, the A-flute next highest, and the solid fiber construction the lowest number of drops. Tests were also made on boxes which had been double-stitched. It may be seen in Table XI that double stitching greatly increased the rough-handling resistance of the A-flute and B-flute boxes.

The compression results for the boxes conditioned 30 days at 85% R.H. and 35°F. are presented in Table XII and graphically in Figure 17. It may be noted that the A-flute box had the highest top-load compression and the B-flute box the lowest. The highest end-load compression was exhibited by the B-flute box and the lowest by the solid fiber box. The box fatigue results at these conditions are also given in Table XII and presented graphically in Figure 18. It may be seen that the A-flute box gave the highest box fatigue values while the B-flute box gave the lowest values.

The over-all conclusion that may be drawn from the tests completed on the three constructions of the Bliss style "Freezur" box appears

TABLE XI

BOX TEST RESULTS
(Conditioned at 85% R.H., 35°F. for 72 Hours and Drop Tested at 85% R.H., 35°F.)

Sample		Drop Test, drops to failure	Cause of Failure
NOD-111 Bliss, B-flute	Max.	36	Staples pulled.
	Min.	10	
	Av.	21 (94)*	
NOD-112 Bliss, Solid fiber	Max.	18	Staples pulled. Vertical score tore.
	Min.	7	
	Av.	10	
NOD-116 Bliss, A-flute	Max.	20	Staples pulled out of top closure.
	Min.	14	
	Av.	16 (108)**	

* Double-stitched ends.

** Double-stitched top closure.

TABLE XII

BOX TEST RESULTS
(Conditioned at 85% R.H., 35°F. for 30 Days, Box Compression Tested at 50% R.H., 73°F., Box Fatigue Tested at 50% R.H., 73°F.)

Sample		End-Load Compression, lb. Max. Load up to 0.50" Defl.	End-Load Compression, lb. Max. Load up to 1.00" Defl.	End-Load Compression, lb. Defl. at Max. Load	Top-Load Compression, lb. Max. Load up to 0.75" Defl.	Top-Load Compression, lb. Max. Load up to 1.00" Defl.	Top-Load Compression, lb. Defl. at Max. Load	Box Fatigue, cycles to failure
NOD-111	Max.	630	690	0.93	980	980	0.67	60
Bliss, B-flute	Min.	525	630	0.73	950	950	0.52	15
	Av.	580	660*	0.83	965	965	0.60	38
NOD-112	Max.	330	400	0.70	1230	1230	0.83	1020
Bliss, Solid fiber	Min.	280	390	0.59	1200	1200	0.65	105
	Av.	305	395	0.65	1215	1215	0.74	905
NOD-116	Max.	540	570	0.60	1510	1510	0.63	5000+**
Bliss, A-flute	Min.	500	500	0.36*	1430	1430	0.55	80
	Av.	515	540	0.53	1465	1465	0.58	1724

* This specimen sustained greater loads at deflections greater than 1.00 inch than it sustained up to 1.00-inch deflection.

** No failure was obtained.

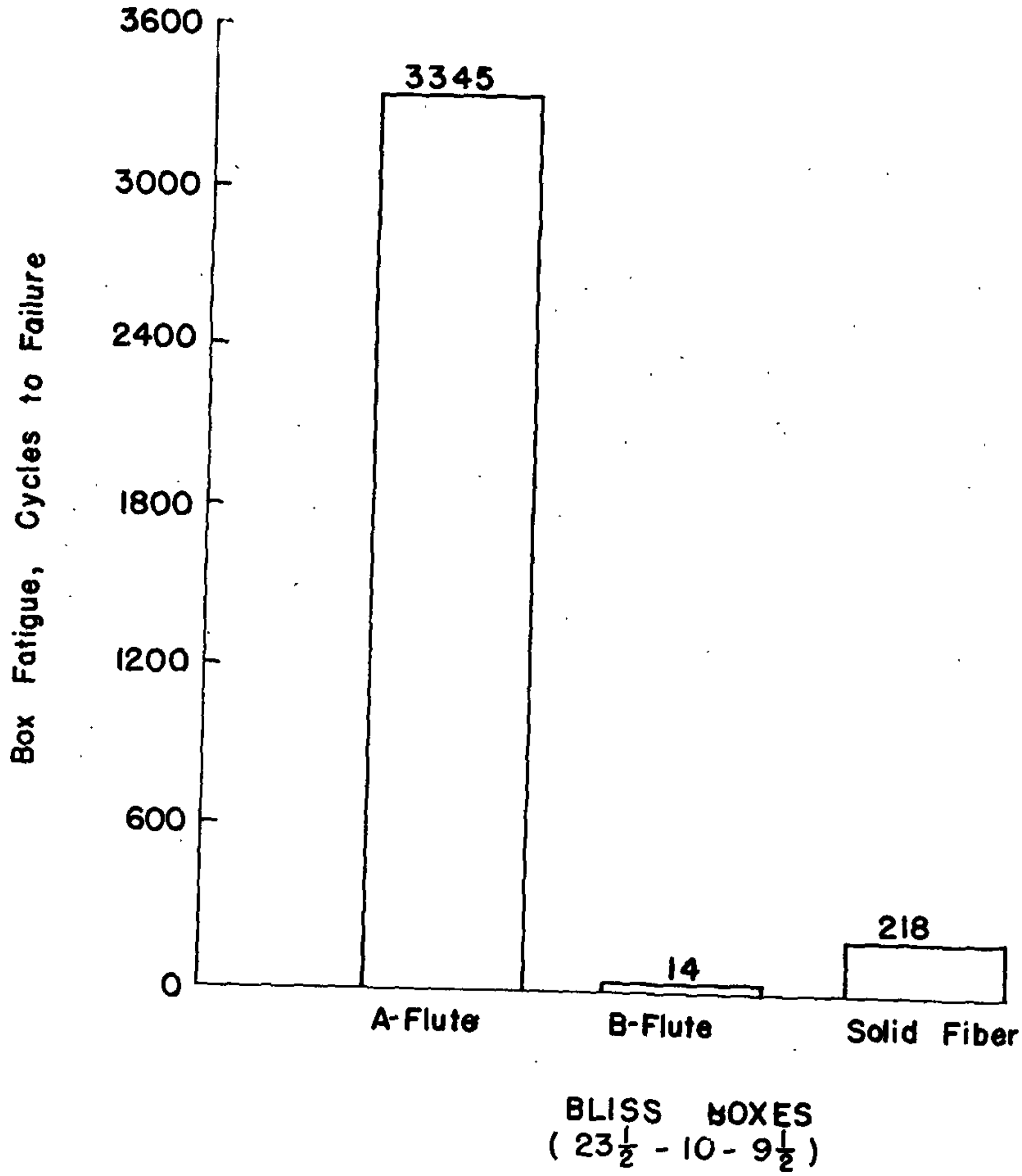


Figure 15

Comparison of Box Fatigue Test Results
(Conditioned 30 days at 85% R.H. and 73°F.)

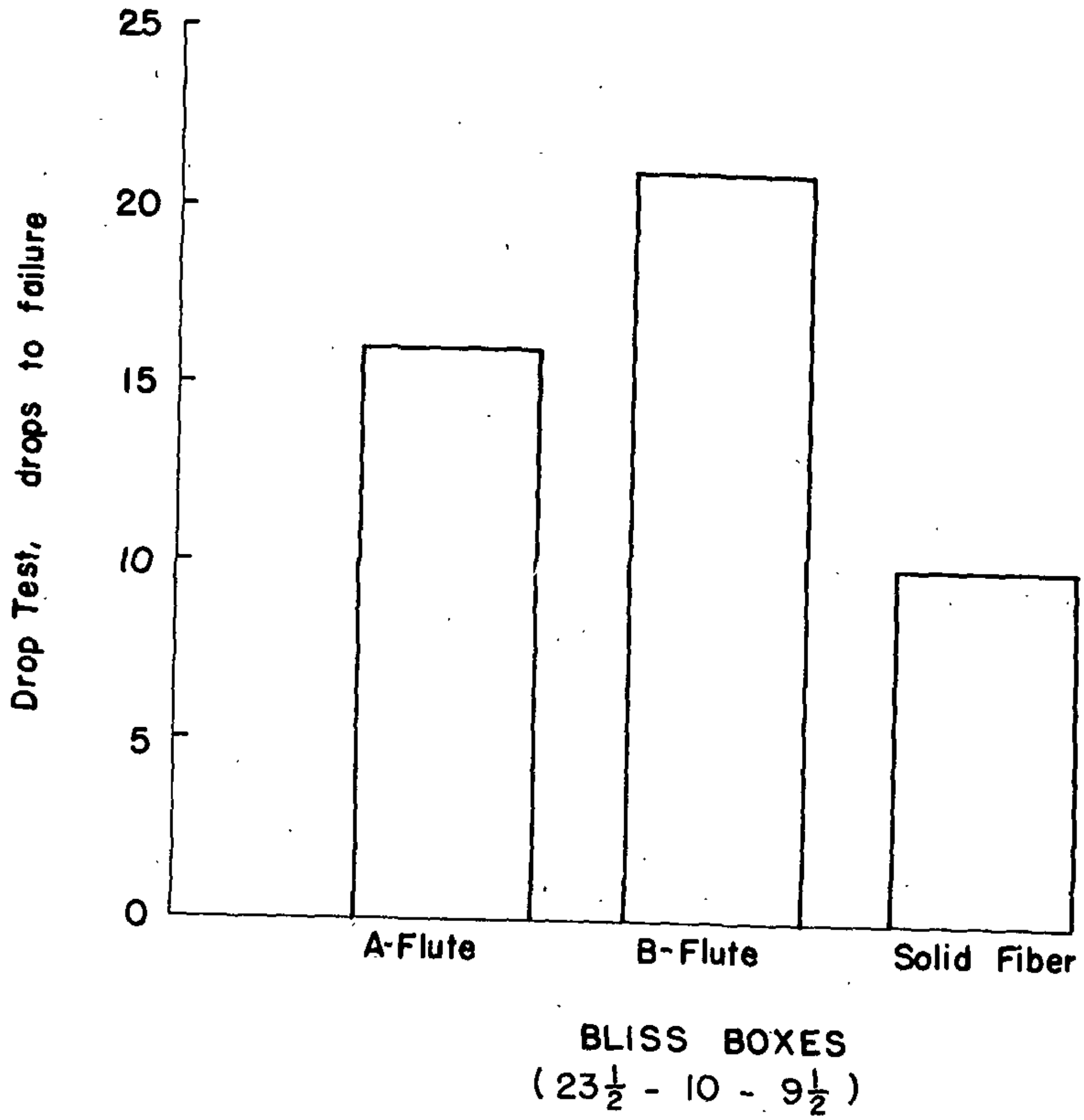


Figure 16

Comparison of Drop Test Results
(Conditioned 72 hours at 85% R.H. and 35°F.)

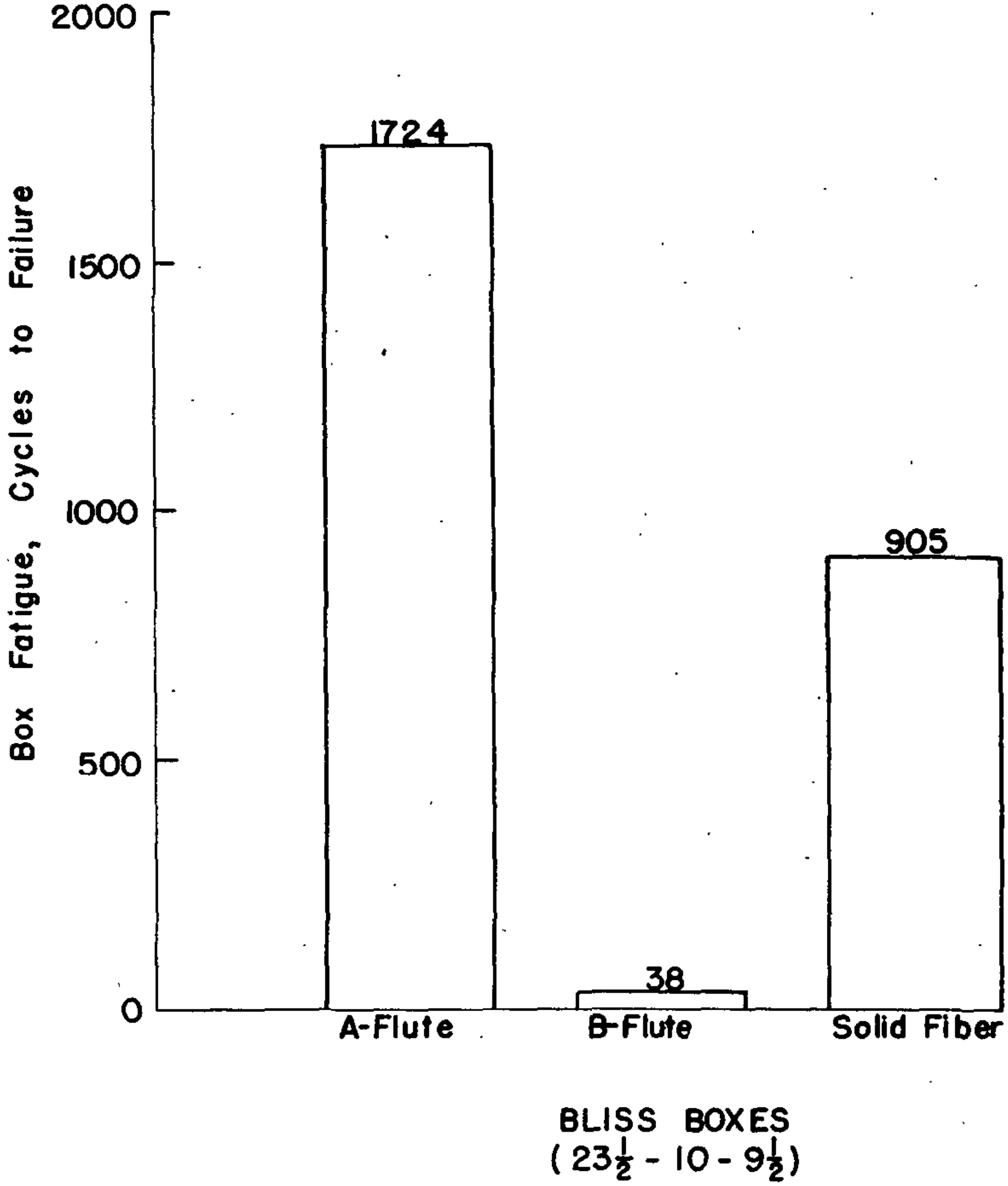


Figure 17

Comparison of Box Fatigue Test Results
(Conditioned 30 days at 85% R.H. and 35°F.)

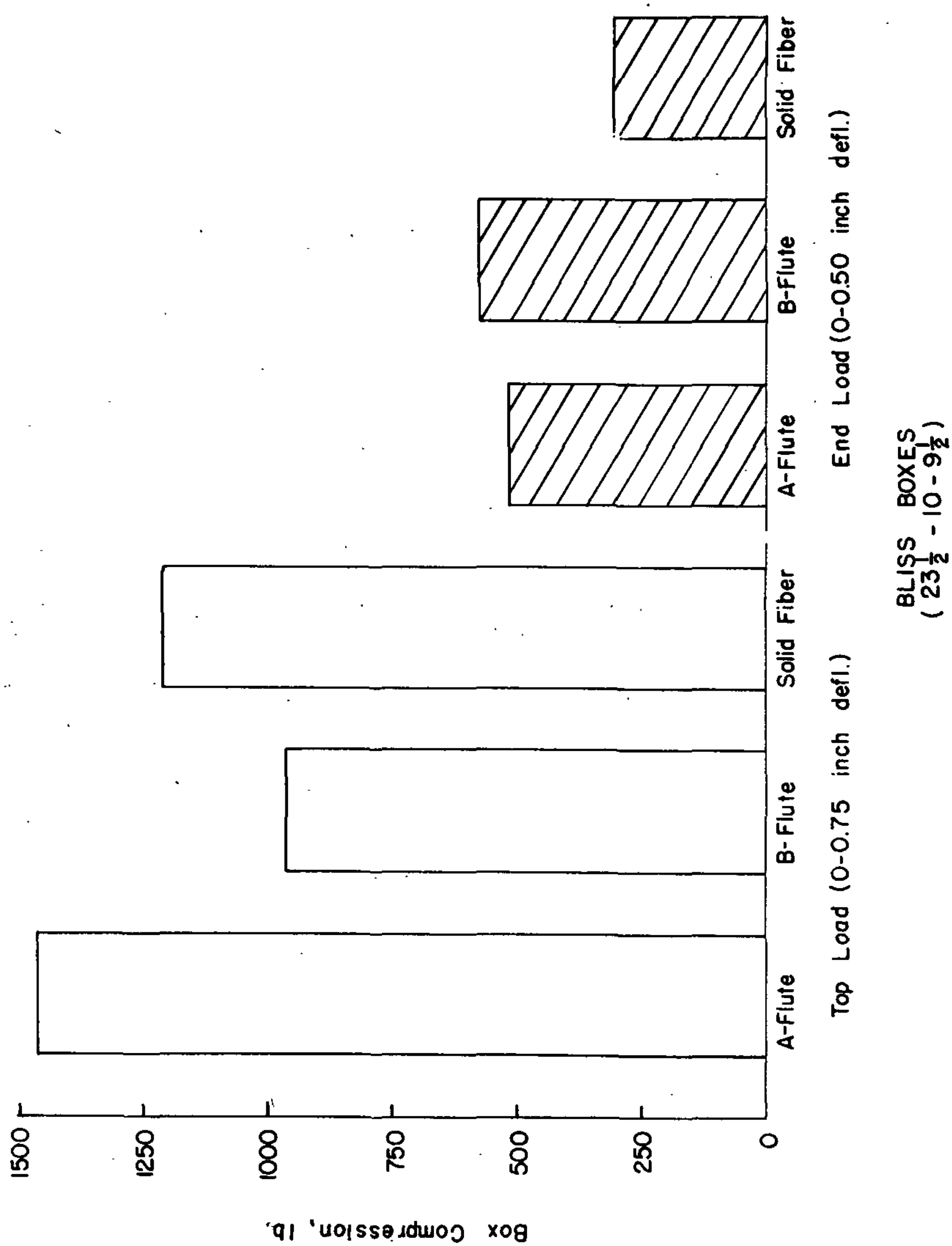


Figure 18

Comparison of Box Compression Results
(Conditioned 30 days at 85% R.H. and 35°F.)

to be that the A-flute construction exhibited superior performance with regard to top-load box compression and box fatigue. Its rough-handling resistance was also good and its end-load compression, although slightly lower than the B-flute construction, was satisfactory. Neither the solid fiber box nor the B-flute box exhibited as good results as consistently as the A-flute box did.

The tests made on the combined board are given in Table XIII. The basis weight results shown in Table XIII indicate that the solid fiberboard was by far the heaviest of the three constructions studied. The bursting strength of the solid fiberboard was the highest and of the A-flute board the lowest. The flat crush values for the B-flute board were considerably higher than the A-flute board as would be anticipated. The machine direction tearing strength of the A-flute board was the highest and that of the solid fiber box body the lowest. However, the cross-machine direction tearing strength of the solid fiberboard was considerably higher than that of the corrugated boards.

TABLE XIII

COMBINED BOARD TEST RESULTS
(Conditioned at 50% R.H., 73°F. for 48 Hours and Tested at 50% R.H., 73°F.)

Sample		Basis Weight, lb./M ft.^{2}	Caliper, points	Bursting Strength, p.s.i.g.	Flat Crush, lb./sq. in.	Torsion Tear, in.-oz. In	Torsion Tear, in.-oz. Across	Torsion Tear, in.-oz. Flap Score	Torsion Tear, in.-oz. Panel Score
NOD-111 (Box Body)	Max.		170.3	540	90.3	392	486	270	364
Bliss, B-flute	Min.		160.2	530	39.3	356	454	240	290
	Av.	290	163.8	472	61.6(10-10-10)	376	472	256	328
NOD-111 (Box Ends)	Max.		162.8	540	83.8	420	496	256	368
Bliss, B-flute	Min.		155.2	410	39.0	370	452	233	340
	Av.	290	159.8	463	63.8(10-10-10)	392	472	248	354
NOD-112 (Box Body)	Max.		104.4	645		336	636	484	304
Bliss, Solid fiber	Min.		100.4	555		280	548	464	250
	Av.	363	102.3	596		316	582	472	273
NOD-112 (Bliss Ends)	Max.		123.0	740		442	740	586	346
Solid Fiber	Min.		115.0	520		384	660	506	296
	Av.	432	119.0	648		418	711	542	316
NOD-116 (Box Body)	Max.		232.5	540	41.7	570	528	500	460
Bliss, A-flute	Min.		222.7	340	31.7	472	462	450	410
	Av.	246	227.0	437	37.0(10-10-10)	531	502	475	441
NOD-116 (Box Ends)	Max.		229.0	520	42.0	558	428	470	426
Bliss, A-flute	Min.		225.0	340	26.3	494	370	394	306
	Av.	247	227.0	427	34.7(10-10-10)	534	400	422	378

SUMMARY

This investigation was undertaken to comparatively evaluate different fiberboard constructions when used as the box material for an "all-purpose" as well as a "Freezur" box in the packaging of meat. The basic idea behind this work was to determine if sulfurized corrugated board would perform equally as well as wood or solid fiber in the packaging of various cuts of meat. It is well known that fiberboard has replaced wood in many instances in the meat industry and it was felt that possibly the treated corrugated box would equal or surpass the performance of the solid fiber, thus, creating new applications for corrugated boxes with their attending economic advantages.

As mentioned above, two box styles were involved in this study: namely, an "all-purpose" box and a "Freezur" box, the latter, as the name implies, intended for storage at subzero temperatures. The R.S.C. "all-purpose" box samples were made from 275-pound stock in solid fiber and A- and B-flute, the latter two being fabricated with sulfur impregnated medium. The 2-4 Bliss style "Freezur" box samples were constructed from solid fiber and A-flute and B-flute corrugated board. The solid fiber box sample was made with a 0.100-point, 350-pound body and 0.120-point, 400-pound ends. The inside of the box was paraffined and waterproof chip was used throughout. The A-flute sample was constructed of 350-pound body and ends as was the B-flute.

The results obtained on the R.S.C. "all-purpose" samples indicate the following:

1. At 50% R.H., the A-flute samples exhibited the highest top- and end-load compression values with the B-flute sample next in order of compression values. The solid fiber sample exhibited the highest corner drop test at 50% and the B-flute the lowest. It should be mentioned that both the A- and the B-flute samples failed in the drop test as a result of the staples either pulling out or unclinching. It is believed that this condition could be remedied by use of a stronger stapling wire which would not pull out as readily.

2. The results obtained on samples conditioned at 85% R.H. at 73°F. show that, in all cases, the corrugated samples equalled or exceeded the compression performance of the solid fiber. In addition, the fatigue tests, using an effective load of 235 pounds, showed that the A-flute sample was vastly superior to either the B-flute or solid fiber sample.

3. The drop test results on samples conditioned at 85% R.H. and 35°F. show that, under this atmospheric condition, the corrugated samples outperformed the solid fiber sample.

4. On the basis of the above results, it would appear that the sulfurized corrugated box will perform equally as well as or better than the solid fiber box under conditions which are encountered in the packaging and storage of meat.

The results obtained on the "Freezur" box (2-4 lb. Bliss) samples show the following:

1. The results at 50% R.H. and 73°F. show that the A-flute sample exhibited higher top- and end-load compression than did the solid fiber sample. Both corrugated samples exhibited better drop performance. The difference in drop results undoubtedly could be increased if the corrugated boxes had been double stitched inasmuch as they failed because the staples became unclinched.

2. At 85% R.H. and 73°F., the A-flute samples also exhibited considerably higher compression values than did the solid fiber sample. The B-flute sample exceeded the solid fiber in end-load compression but was slightly less in the case of top-load. The fatigue characteristics of the A-flute samples under an effective load of 750 pounds were markedly superior to the other samples.

3. The drop test results on samples conditioned for at least 72 hours at 85% R.H. and 35°F. showed that the corrugated samples exhibited a greater retentive capacity than the solid fiber sample.

4. The test results on the samples stored for 30 days in an atmosphere maintained at 85% R.H. and 35°F. showed that the A-flute sample was superior to the solid fiber sample in terms of compressive resistance as shown by the conventional compression test results as well as fatigue in compression.

5. The above results indicate that the sulfurized board can be made to perform equally as well as or better, in terms of physical

properties, than solid fiber in the handling and storage of commodities such as meat requiring resistance to compression and high retention at high moisture conditions. This should be of particular interest because the 2-4 Bliss boxes were made with only double-faced ends. If the ends had been made of double-wall board, it is believed that the performance would have been much better. Also, double-stitching or the use of heavier stitching wire would also increase the retention of the corrugaged sample.

Since the initiation of this study, successful applications of sulfurized board have been made in the meat industry and the use of this type of board by the Bureau of Animal Industry has been cleared.